FINAL REPORT
BALBOA AND FRANCISCO RESERVOIRS
NEEDS ASSESSMENT

SUBMITTED TO

PUBLIC UTILITIES COMMISSION

CITY AND COUNTY OF SAN FRANCISCO

SAN FRANCISCO WATER DEPARTMENT

MARCH 1990

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Submitted To
Public Utilities Commission
City and County of San Francisco
San Francisco Water Department
March 1990

The following report and associated engineering studies were prepared under the direction of a registered civil engineer in the State of California.

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EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this study is to determine whether City water needs and the hydraulic and public safety benefits of the Balboa and Francisco reservoir sites mandate their integration into the City of San Francisco (City) water distribution system. The association of Leedshill-Herkenhoff, Inc. and AGS, Inc. (LH/AGS) was commissioned to perform this study by the City Public Utilities Commission.

The 150-million-gallon Balboa Reservoir consists of two basins located adjacent to City College of San Francisco in the south-central portion of the City. Construction was initiated as a WPA project in the 1930's and was completed in the late 1950's. The basins are formed by earthen berms with interior asphalt-concrete lining, and are unroofed. The reservoir was never connected to the City system and has never been filled. The north basin is currently used as a parking facility for City College.

The 2.5-million-gallon Francisco Reservoir, located on Russian Hill, was constructed in 1861. Its single basin is brick lined and covered with a deteriorating timber roof. Francisco Reservoir was gradually displaced by other facilities as the City grew and was disconnected from the distribution system in the early 1970's. The Marina and North Beach areas previously served from Francisco Reservoir are now supplied from University Mound Reservoir.

The method of approach employed in this study was to first establish design and evaluation criteria and to assess future water needs. Using these criteria, computer models of the water distribution system were formulated to analyze system hydraulics and to identify potential reservoir benefits. Each reservoir

was next evaluated to determine the structural and technical feasibility of its rehabilitation and placement into service. The results of these studies were used to formulate the recommended alternative.

CRITERIA AND WATER NEEDS

Study criteria were formulated from discussions with City personnel and from LH/AGS experience in similar studies. These criteria were approved by City staff before their use in system evaluation.

The following are adopted criteria goals:

1) Limit distribution system pressures to between 40 and 90 pounds per square inch under normal conditions, with 20 pounds per square inch acceptable during fire fighting demands.

2) Limit pipe velocities and friction losses, which increase with increasing flow, to ten feet per second and five feet per 1000 feet of pipe, respectively.

3) Use pipe roughness factors determined from measured and theoretical values based on pipe age and material, modified to reflect the City's mortar-lining program.

4) Determine maximum day and peak hour demands as 150% and 225%, respectively, of average day demand.

5) Adopt year 2035 demand as representative of ultimate City demand, and distribute in proportion to existing demands.

6) Circulate reservoir storage at least once per week to avoid stagnation.

7) Base seismic design on the maximum credible earthquake.

8) Use piping costs taken from recent City bid tabulations.

Average day City water use was about 96 million gallons per day in 1985. It is estimated that City-wide average day water demand could increase to 110.5 million gallons per day by the year 2035. This demand has been adopted as the ultimate City demand for planning purposes. Using the adopted peaking factors of 150% and 225% results in a maximum day demand of 165 million gallons per day and peak hour use at a 249 million-gallons-per-day rate.

Fire fighting demands have been determined from San Francisco Fire Department guidelines. These demands vary by pressure zone, range from 2000 to 18,000 gallons per minute, and are to be sustained for 12 hours while maintaining a residual pressure of at least 20 pounds per square inch. San Francisco has a high pressure fire supply system separate from the domestic supply system. However, the Fire Department requires that the domestic water system independently meet fire fighting demands.

Emergency storage reserves are required both to supply fire fighting demands and to provide a potable drinking water supply in the event of an interruption in water supply system deliveries. Emergency storage, currently about a 3.5-day supply at average day demand, will decline to a 3.0-day supply under ultimate average day demand conditions. A catastrophic event, such as a major earthquake on the San Andreas fault, could isolate the City from the Peninsula source of supply for one to two weeks. Domestic water use during the period immediately following a major catastrophe could be restricted to 50 percent or less of normal usage. Supply of three and one-half to seven days of normal usage (one to two weeks' rationed usage) of gravity-feed potable water storage has been adopted as the desired emergency storage reserve.

The above study criteria and water needs were used to formulate computer models to analyze the water system hydraulics, to identify potential reservoir benefits, and to determine structural and technical feasibility of reservoir rehabilitation. A recommended alternative was determined from these analyses.

BALBOA RESERVOIR

<u>Hydraulic analyses and potential reservoir benefits</u>: Hydraulic computer models of the Sunset and College Hill pressure zones were formulated to determine potential pressure benefits to be derived from Balboa Reservoir. It was found that the southernmost portion of the College Hill zone would experience low pressures under maximum day, peak hour, and fire fighting demands, and would benefit from connection to Balboa Reservoir. The portion of the zone in the Western Addition could also benefit from Balboa pressure, but the costs of the piping required to connect this area is not justified by the benefit. College Hill Reservoir holds a water volume approximately equal to the fire-fighting

volume, or about one day of year 2035 average day demand. With supplementary storage available from Sunset Reservoir, a combined 2.9 day supply is available to College Hill Reservoir. This reserve is not adequate to meet the 3.5- to 7.0-day reserve supply criterion. Supply of College Hill from Balboa Reservoir would increase emergency storage to 3.8 days if one basin is used, or to 5.0 days if both basins are used. However, **the demand of the College Hill pressure zone is only adequate for weekly circulation of a single Balboa Reservoir basin. Weekly circulation is necessary to avoid stagnation and maintain high water quality.**

Technical and structural feasibility: Available subsurface data from previous studies were used in finite element analyses of the dynamic response of the Balboa Reservoir embankment to the maximum credible earthquake of 8.3 Richter scale magnitude occurring on the San Andreas fault. The results of these analyses indicate that soils in the southwest corner of the north basin are liquefiable. To mitigate the liquefaction potential, either the Balboa Reservoir should be lined or the liquefiable soils grouted. The existing design for the south basin roof has been evaluated and found to be satisfactory. Supply of Balboa Reservoir through the Alemany Pump Station was found to be the supply route least expensive to operate. Connection of Balboa Reservoir to Alemany Pump Station and the College Hill pressure zone would require 12,200 feet of 36-inch water main paralleling the Crosstown Pipeline in Circular Avenue. Alemany Pump Station would require addition of an emergency power source at additional cost.

Recommendations: LH/AGS recommend renovation and roofing of a single Balboa Reservoir basin and piping connection to the City system. Insufficient soils information for the south basin does not allow recommendation of a particular basin. It is recommended to supply Balboa Reservoir from the Alemany Pump Station, and to use the reservoir to supply the College Hill pressure zone. Total cost for renovation, roofing and piping connections for a single basin is estimated at $27.1 million, exclusive of upgrades to Alemany Pump Station.

FRANCISCO RESERVOIR

Hydraulic analyses and potential reservoir benefits: The Marina District, formerly served by Francisco Reservoir, is now part of the University Mound pressure zone. Computer analyses show the distribution piping in the Marina to

be inadequate under maximum day, peak hour, and fire fighting demands. Increasing the hydraulic efficiency of the University Mound delivery system is not practical. However, raising a rehabilitated Francisco Reservoir ten feet to an overflow elevation of 145 feet would solve most low pressure problems. The resulting 5.8-million-gallon reservoir would supply an additional 2.6 days of local emergency storage for the Marina District for a total 5.4-day reserve supply, which meets the 3.5- to 7.0-day reserve supply criterion. Francisco Reservoir would be refilled by gravity flow from University Mound Reservoir.

Technical and structural feasibility: Raising Francisco Reservoir to an overflow elevation of about 145 feet would provide pressure benefits and compatibility with the present water supply system. Existing geologic and geotechnical data indicate that bedrock underlies the reservoir at relatively shallow depth, and appears adequate to support a raised reservoir. The conceptual design of such a reservoir would replace the brick lining with a concrete slab, raise the berms ten to fifteen feet, and replace the deck, roofing, and columns with a concrete structural system. Approximately 1600 feet of piping and miscellaneous valving is required to connect Francisco Reservoir into the distribution network. An additional 7700 feet of distribution system piping is required to remedy low fire fighting pressures in the Marina District.

Recommendations: LH/AGS recommend that the City rebuild Francisco Reservoir to a capacity of 5.8 million gallons with an overflow elevation of 145 feet and use it to serve a new pressure zone encompassing the Marina District, at an estimated cost of at least $4.3 million. An additional $0.8 million of piping improvements are also recommended to meet fire flow requirements in the Marina District.

CHAPTER 1

INTRODUCTION

BACKGROUND

Balboa and Francisco Reservoirs are unutilized facilities in the San Francisco Water Department (SFWD) Distribution system. Construction of Balboa Reservoir was initiated as a WPA project in the 1930's, and was completed to its present condition in the late 1950's. Balboa's two basins totaling 150 million gallons (MG) have never been filled but their geographical location and elevation present opportunities for integration with and improvement of the City's water supply system. San Francisco City College has identified other uses of the Balboa site in its long term plan, and the Water Department desired a reassessment of the City's long-term goals and needs. The 2.5 million gallon Francisco Reservoir was constructed in 1861 and was gradually displaced by other facilities, and is now isolated from the system. Though aging and located at a low hydraulic elevation, Francisco's Russian Hill location could benefit portions of the City distribution system most remote from the source of supply.

Balboa Reservoir is located in the south-central portion of the City, and is indicated as reservoir 28 on the pressure zone map presented in Figure 1-1. Francisco Reservoir is located in the northeast portion of the City, and is indicated as reservoir 40 in Figure 1-1. This figure also presents a schematic representation of how the reservoirs are connected into the distribution system, and shows their relative elevations. The Crosstown Pipeline extending from the 54-inch San Andreas pipeline to University Mound Reservoir runs by the Balboa site, and is the logical supply source to Balboa Reservoir. Although this schematic shows that Francisco Reservoir is connected to University Mound Reservoir, pipelines from both Sunset and Lombard Reservoirs are also available to supply Francisco. Piping connections to Francisco Reservoir were removed in the early 1970's.

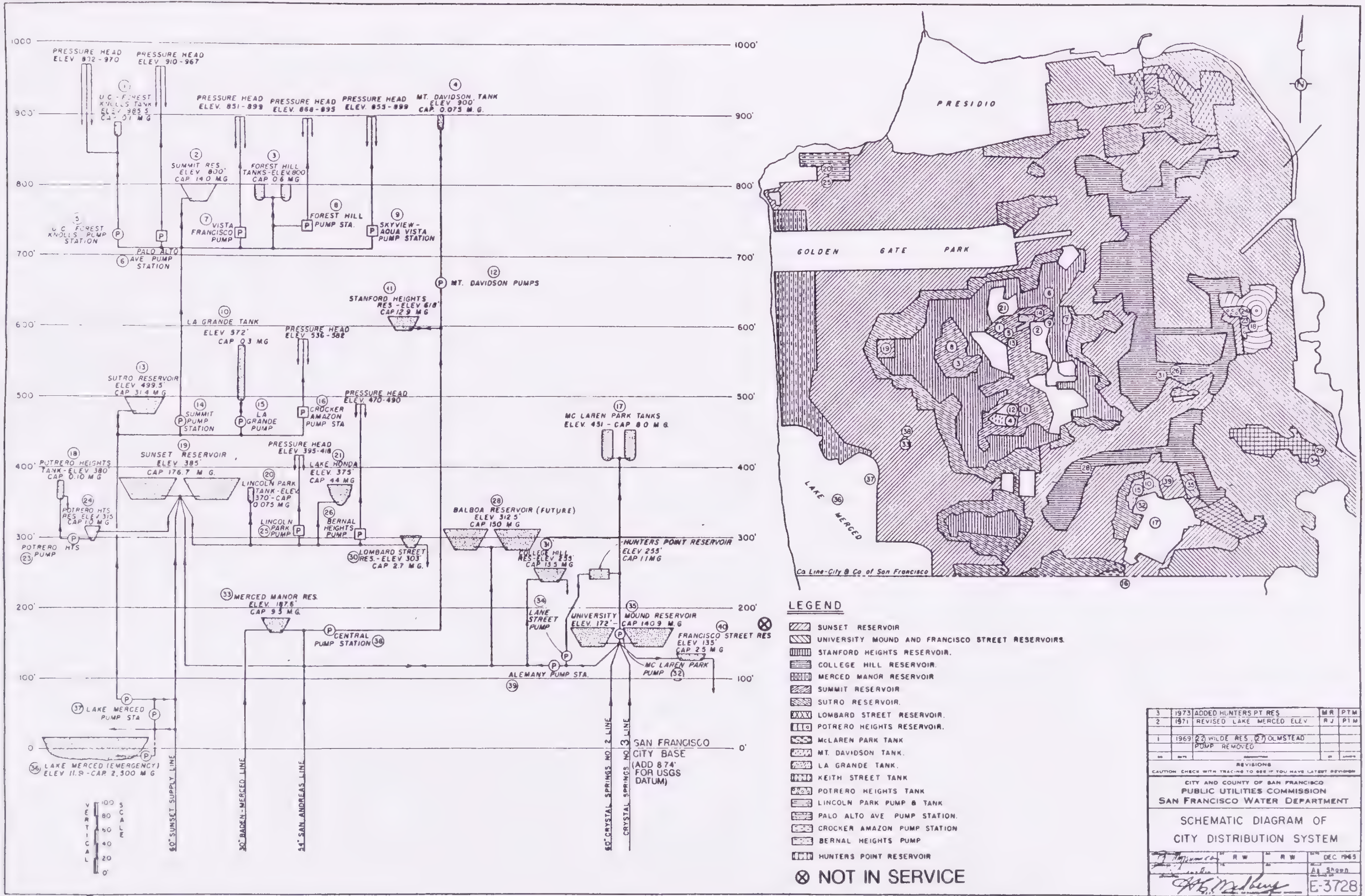

FIGURE 1-1

City of San Francisco Water Department/UEB

BALBOA/FRANCISCO RESERVOIRS NEEDS ASSESSMENT

Schematic Diagram of City Distribution System

PURPOSE

The purpose of this study is to determine whether City water needs and the hydraulic and public safety benefits of the Balboa and Francisco Reservoir sites mandate their integration into the City water distribution system. Three principal questions are addressed:

(1) Are the <u>needs</u> for Balboa and Francisco Reservoirs sufficient to justify incorporation into the water distribution system?
(2) What <u>benefits</u> will be derived from use of these sites?
(3) Is it <u>feasible</u> to incorporate Balboa and/or Francisco reservoirs into the system?

Use of these sites is evaluated for their ability to:

- Remedy existing deficiencies
- Provide for future growth
- Provide emergency storage
- Reduce operation and capital construction costs

SCOPE OF WORK

This project assessing the needs for Balboa and Francisco Reservoirs involved three principal phases. The first phase included data collection and review, quantification of future water requirements and emergency storage needs, and identification of existing distribution system deficiencies. The second phase assessed geotechnical and structural feasibility of using the two sites and included site reconnaissance inspections, geotechnical and engineering analyses, and preparation of remedial conceptual designs and cost estimates. The third phase involved hydraulic modeling of the distribution system to determine benefits of incorporating the two reservoirs into the system. This task included review of City operation parameters, development of the hydraulic models, optimizing the distribution system piping and pressure zones, and analyses of capital and operational costs of alternative system improvements. The above three phases lead to the recommendations presented in the final chapter of this report.

AUTHORIZATION

The work described herein was authorized by Public Utilities Commission Resolution number 89-0246 dated July 25, 1989. Notice to proceed was given at the kick-off meeting held on September 10, 1989.

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LIST OF ABBREVIATIONS

ABAG	Association of Bay Area Governments
AGS	AGS, Inc.
AWSS	auxiliary water supply system
BG	billion gallons
Cap.	capacity
CDD	SFWD City Distribution Division
CDM	Camp Dresser and McKee
C-factor	Hazen-Williams pipe roughness factor
cfs	cubic feet per second
CS	Crystal Springs
DMJM	Daniel, Mann, Johnson and Mendenhall
DOF	State Department of Finance
elev.	elevation relative to San Francisco City Base
EA	each
EBMUD	East Bay Municipal Utility District
EPS	extended period simulation
ESA	Earth Science Associates
g	Acceleration of Gravity
gpcd	gallons per capita-day
gpm	gallons per minute
HPSS	high pressure supplementary fire supply system
KYPIPES	University of Kentucky pipe distribution system model
LF	lineal foot
LH	Leedshill-Herkenhoff, Inc.
mgd	million gallons per day
MG	millon gallons
MKE	Morrison-Knudsen Engineers
MSL	mean sea level
P/L	pipeline
PRV	pressure reducing valve
P/S	pump station
psi	pounds per square inch
Res.	reservoir
SCADA	Supervisory Control and Data Acquisition system
SFFD	San Francisco Fire Department
SFWD	San Francisco Water Department
SPT	Standard Penetration Test

UEB	San Francisco Utilities Engineering Bureau
WPA	Work Projects Administration
WRA	Water Resource Associates
WTP	Water Treatment Plant

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CHAPTER 2

NEED FOR BALBOA AND FRANCISCO RESERVOIRS

OVERVIEW OF FACILITIES

The City of San Francisco is subdivided into eleven principal pressure zones, each fed by gravity from reservoirs with capacities ranging from 1.1 to 176.7 million gallons. There are also numerous smaller pressure zones, mostly at high elevations, which are served from tanks of less than one million gallon capacity, or are pump-pressurized with hydropneumatic tanks. Table 2-1 lists the storage and overflow elevation for each of the principal pressure zones. Pressure zones are commonly referred to by the reservoir overflow elevation. For example, "385 service" refers to the Sunset pressure zone which has its overflow at an elevation of 385 feet. Table 2-1 shows over 412 million gallons (MG) of gravity-flow, potable water storage within the City. Completion of both Balboa Reservoir basins and rehabilitation of Francisco Reservoir could add more than 150 million gallons of storage, an increase of more than one-third of existing storage.

To determine the need for Balboa and Francisco Reservoirs it was necessary to examine several pressure zones and associated reservoirs within the City. The area previously served by Francisco Reservoir is now a part of the University Mound pressure zone. Portions of College Hill and Sunset pressure zones could be served from Balboa Reservoir. Taken together, University Mound, College Hill, and Sunset pressure zones account for about 80 percent of the total City demand. Pressure zone boundaries are shown in Figure 1-1.

<u>Balboa Reservoir</u>

The two Balboa Reservoir basins are located near San Francisco City College on Ocean and Phelan Avenues. When filled, the total capacity of the two reservoir basins would be 150 million gallons at an overflow elevation of 312 feet. The two asphalt-concrete lined basins have never been used for water storage. The north basin is presently used as a parking lot for the College. There is a pipe connecting the two basins, but no supply or service lines are connected to either basin. In order to fill and use the basins it may be necessary to repair small cracks in the lining or reline the entire reservoir.

Table 2-1

Pressure Zone Elevation and Storage

Reservoir Pressure Zone	Date Built	Overflow Elevation (Feet)	Zone Storage (MG)
Merced Manor	1936	188	9.50
Stanford Heights	1923	618	12.98 /1
College Hill	1870	255	13.50
University Mound	1885	172	140.90
McLaren Park	1966	451	8.00
Hunters Point	1973	255	1.10
Sutro	1952	500	31.40
Summit	1954	800	14.70 /2
Potrero	1897	315	1.10
Lombard	1860	303	2.70
Sunset	1938	385	176.78 /3
			412.65
Inactive:			
Francisco	1861	135	2.50
Balboa	1957	312	150.00 /4

/1 Stanford Heights(12.9)+Mt. Davidson(0.075)
/2 Forest Knolls(0.1)+Summit(14.0)+Forest Hill(0.6)
/3 Sunset(176.7)+Lincoln Park(0.075) excludes Laguna Honda(44.0)
/4 Construction not completed. Two basins of approximately 75 MG each.

College Hill Reservoir and Service Area

College Hill Reservoir consists of a single basin with a capacity of 13.5 MG at an overflow elevation of 255 feet. The reservoir was constructed in 1870. It is located near Holly Park in Bernal Heights in the southeastern part of the City. The reservoir was re-lined with asphalt and covered with a tar and gravel timber roof in 1959-60. The reservoir serves a small area along the I-280 freeway to the south, with most of its service area to the north along Guerrero Stre[illegible] in the Mission District. It also serves San Francisco General Hospital and a small area to the north. The reservoir is fed either from the 54-inch San Andreas pipeline which originates at the San Andreas Water Treatment Plant or from Sunset Reservoir. Before entering the reservoir the water passes through

a pressure reducing valve (PRV) at Roanoke Street where pressures are reduced to about 50 psi. From the PRV roughly 10 million gallons per day (mgd) pass through the reservoir and about 2 mgd feed the southern portion of the pressure zone directly off the PRV. Presently the College Hill pressure zone is somewhat strained with several low pressure areas noted in the northern fringes of the system in the Western Addition and Chinatown areas.

Sunset Reservoir and Service Area

Sunset Reservoir is the largest of the City's storage facilities with a capacity of 176.7 million gallons. It has an overflow elevation of 385 feet. Sunset Reservoir is located in the western part of the City along 28th Avenue. Its large service area forms a loop around Twin Peaks and serves elevations from about 60 to 300 feet. The Sunset pressure zone includes the Sunset and Richmond Districts in the western half of the City, and extends east into Chinatown. The Sunset zone also includes a narrow band to the east of Twin Peaks adjacent to the College Hill service area. To the south, the Sunset pressure zone covers a fairly extensive area around College Hill Reservoir and along the southern border of the City. This southern area is sometimes fed directly from the 54-inch supply line from the San Andreas Treatment Plant. This pipeline also feeds the entire College Hill pressure zone through the PRV at Roanoke Street. In addition, Sunset Reservoir feeds two smaller satellite reservoirs, Lombard and Potrero. There are several high pressure areas noted in low elevation areas of the Sunset service area.

Lombard Reservoir And Service Area

Lombard Reservoir, built in 1860, is the oldest reservoir in the San Francisco system. It has a capacity of 3.3 million gallons, with an overflow elevation of 303 feet. The reservoir was excavated, is lined with asphalt, and shows no signs of leakage. The concrete roof has tennis courts on top and is considered to be in good condition. Lombard Reservoir, located on Russian Hill, is supplied from Sunset Reservoir and serves a relatively small area consisting of the intermediate elevations on Russian, Nob, and Telegraph Hills. There are some low pressure areas noted within this pressure zone in the Telegraph Hill area. A 12-

inch pipeline, now severed, connected Lombard with Francisco Reservoir, located two blocks to the north and some 188 feet down-slope.

University Mound Reservoir and Service Area

The two University Mound Reservoir basins have a total capacity of 140.9 MG with overflow elevation of 172 feet. The reservoir is located in the southeastern part of San Francisco at University and Felton Streets. It serves an area that is bordered by San Francisco Bay to the east and north, and extends inland to an elevation of about 90 feet. The reservoir serves the Bayview District west to Freeway 101, the Mission District west to Valencia Street, the South of Market District, and most of Downtown, North Beach, and the Marina District.

Francisco Reservoir

Francisco Reservoir is located on Russian Hill in the northern part of San Francisco at Hyde and Francisco Streets. Built in 1861, it has a total capacity of 2.5 million gallons with an overflow elevation of 135 feet. The reservoir has a brick-lined bottom and a deteriorating asphalt/gravel-covered timber roof. The reservoir is not presently being used and has been valved-off from the system for about 30 years. Pipeline connections to the reservoir were subsequently severed during renovation of the Hyde Street cable car line in the early 1970's. Inlet and outlet valves are still in place. Use of Francisco Reservoir was discontinued because the water could not cycle (exchange water daily) and would stagnate.

Gate Book[1] drawings show that a 12-inch connection from the Sunset and Lombard lines was normally used to supply Francisco. University Mound was also used as a source of supply. The area previously served from Francisco is now part of the University Mound pressure zone.

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[1] Water Department "Gate Books" are detailed maps of the distribution system piping.

The Francisco site could allow expansion in width of up to 45 feet south of the existing reservoir to the base of the adjacent cut slope. An increase in height of at least 30 feet is possible without obstructing views from nearby home owners.

SOURCE OF SUPPLY

The water supply system was analyzed to determine its capability to handle higher future deliveries to existing or renovated reservoirs. The San Francisco water supply has its source on the Tuolumne River in the Sierra Nevada. The City's Hetch Hetchy system conveys this water through closed conduits across the Central Valley, through the Coast Range, and onto the Peninsula entirely by gravity. Supply lines converge at the east portal of the Pulgas Tunnel. Water from the tunnel enters the City system either directly through the Crystal Springs Bypass Tunnel and pipelines, or is discharged into Crystal Springs Reservoir, pumped to San Andreas Reservoir, treated at the San Andreas Water Treatment Plant, and conveyed to the City through the San Andreas pipelines. Figure 2-1 shows schematically the supply system plumbing from the Pulgas Tunnel to the City terminal reservoirs.

Pulgas Tunnel to Reservoir Supply Mains

Water enters the City system through the 10.25 ft. diameter Pulgas tunnel. The flow from this tunnel is either spilled into Crystal Springs Reservoir, or transported north via the Crystal Springs Bypass Tunnel and pipelines.

The Pulgas Pump Station in conjunction with the Crystal Springs Balancing Reservoir operate to maintain the water surface elevation in the Pulgas tunnel within certain operation ranges. When the water surface elevation in the tunnel rises above the desired operating range to elevation 301 feet, water is pumped into Crystal Springs Balancing Reservoir. If the water surface rises over 303 feet, it is spilled into Crystal Springs Reservoir. When the water surface elevation drops below 301 feet, water is released from Crystal Springs Balancing Reservoir through a pressure reducing valve back into the tunnel.

A portion of the Pulgas tunnel flow is diverted into the Crystal Springs Bypass system. This system delivers water through a series of tunnels and pipelines that eventually become the 60-inch Sunset Supply Line and the Crystal Springs No. 2 and No. 3 pipelines[2]. The 60-inch Sunset Supply line extends to Lake Merced Pump Station where the head is boosted to Sunset Reservoir pressure. Crystal Springs No. 2 and No. 3 pipelines extend from the Crystal Springs bypass system and flow by gravity to University Mound Reservoir.[3]

Water from Crystal Springs Reservoir is pumped via Crystal Springs Pump Station to the 6.2 billion gallon San Andreas Reservoir. This water is then pumped to and treated at the 80 mgd San Andreas Water Treatment Plant and discharged to the 6.5 MG finished water reservoir. Water is then discharged through a 78-inch outlet pipe which connects to the 60-inch Sunset Branch line, the 66-inch San Andreas No. 3, and 54-inch San Andreas No. 2 pipelines at the San Pedro Valve Lot. The 54-inch San Andreas line continues on to feed a portion of the Sunset pressure zone, and connects to the Crosstown Pipeline. The Crosstown Pipeline runs past the Balboa Reservoir site and on to College Hill pressure zone via the Roanoke Valve Vault.

Reservoir Supply Lines

There are four main service lines that enter into the City's reservoir system; the 60-inch Sunset Supply line, 30-inch Baden-Merced line, the 54-inch San Andreas, and the 60-inch Crystal Springs No. 2 supply lines. The Baden-Merced line that serves the Merced Manor Reservoir is not used, and may be abandoned.

60-inch Sunset Supply line. The 60-inch Sunset Supply line extends through the Lake Merced Pump Station to the 176.7 MG Sunset reservoirs.

54-inch San Andreas line. The 54-inch San Andreas line is a supply line for College Hill Reservoir and Sunset pressure zone. The origin of this pipeline can be the San Andreas Water Treatment Plant at an elevation of about 465 feet. Flow

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2 Crystal Springs No. 1 pipeline was abandoned in the 1970's.

3 Crystal Springs No. 3 pipeline supplements the No. 2 pipeline. Portions of Crystal Springs No. 1 pipeline are being renovated.

City of San Francisco
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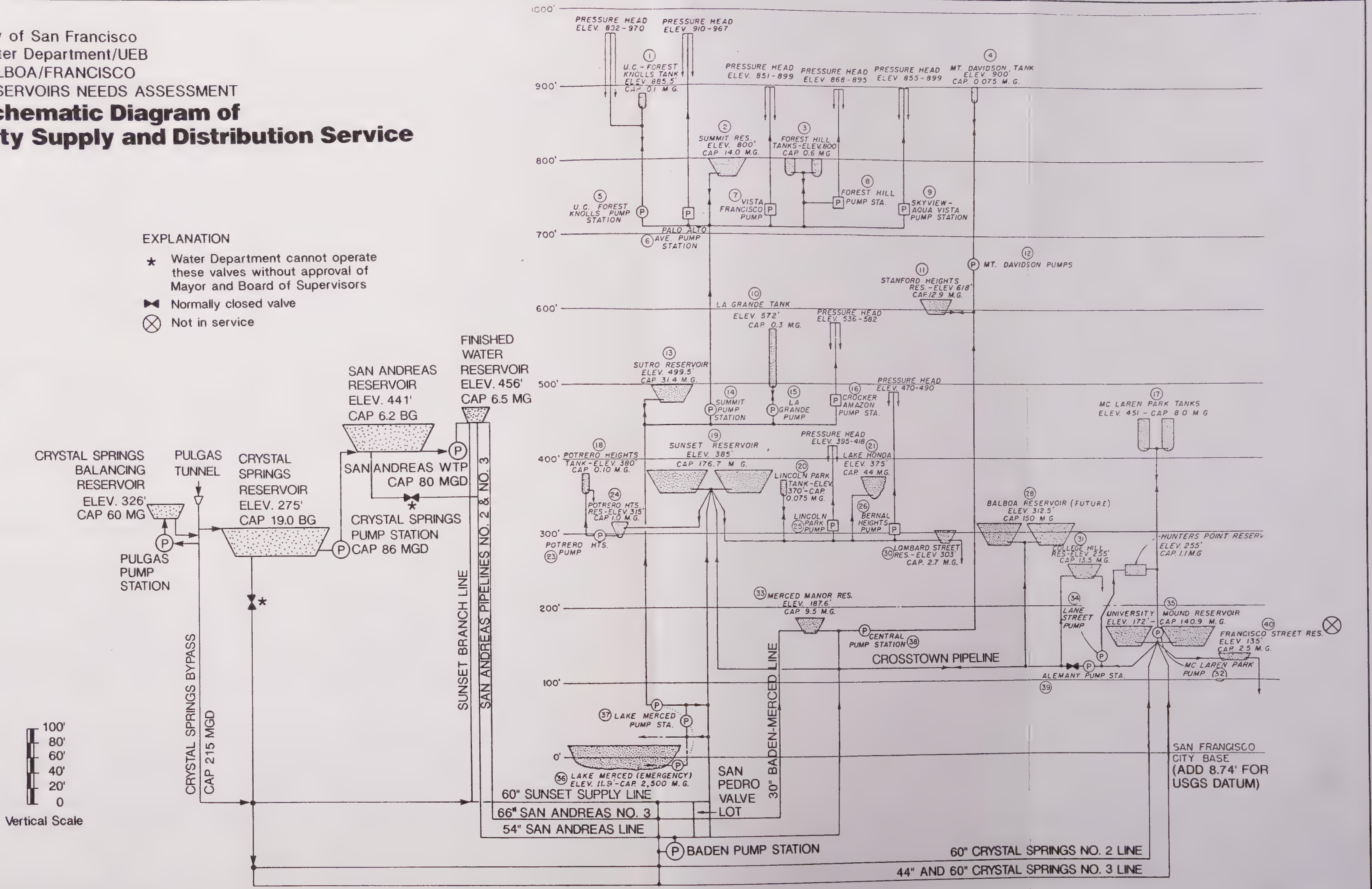
BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Schematic Diagram of City Supply and Distribution Service



SOURCE: City Drawing E-3728-3, 12/65.

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from the plant can be throttled at the San Pedro Valve Lot to Sunset pressure to feed the southern portion of the zone directly. The remainder of the flow passes through the Roanoke Valve Vault before supplying the College Hill reservoir and a southern section of the College Hill zone.

<u>60-inch Crystal Springs No. 2 pipeline</u>. This pipeline is part of the Crystal Springs Bypass which flows into the 140.9 MG University Mound Reservoir. University Mound Reservoir is also connected to the Alemany Pump Station and to the College Hill system via the Crosstown Pipeline. Alemany Pump Station is located at University Mound Reservoir. Crystal Springs No. 3 pipeline, which parallels the No. 2 pipeline, consists of new 60-inch pipe and renovated portions of the 44-inch Crystal Springs No. 1 pipeline.

<u>Crosstown Pipeline</u>. The 44-inch Crosstown Pipeline branches off of the San Andreas line and runs northeast toward College Hill reservoir. At the junction with the 36-inch College Hill feeder, the pipeline enlarges to 44 inches and continues to the Alemany Pump Station. This connection allows water to be pumped from University Mound into the College Hill, Sunset or Balboa distribution systems via the Alemany Pump Station.

WATER QUALITY ASSESSMENT

City staff stated that there are no water quality problems within the City distribution system. The current source of water for Sunset and University Mound Reservoirs is the Hetch Hetchy Aqueduct. Water flowing from the Sierra Nevada through this completely enclosed aqueduct is so pure that only chlorination is presently necessary. Although the Hetch Hetchy water source is very pure, current regulations require that all surface waters for potable use be filtered in the future.

Water supplied to College Hill Reservoir and to southern parts of the City along the Crosstown Pipeline passes through both Crystal Springs and San Andreas Reservoirs on the Peninsula. Water from these open reservoirs must be treated at the San Andreas Treatment Plant before entering the domestic distribution system. Water from the East Bay Calaveras and San Antonio Reservoirs is treated

at the Sunol Water Treatment Plant. Automatic chlorination equipment is installed on the outlets of ten reservoirs.[4]

The north basin of Balboa Reservoir has been used for parking for years. If this basin is to be used, it must be thoroughly cleaned and/or lined to prevent oil contamination of the water supply.

WATER DEMAND PROJECTIONS

Existing projections and historical data for City population and water use were reviewed and evaluated to provide an estimate of the ultimate City water demand. Projected water demand data are available through year 2035. LH and City staff have assumed 2035 demands are representative of ultimate demands for the purposes of this study. Trends in population growth and per capita water consumption were reviewed to establish a likely range for this demand. In general, water consumption has declined significantly due to two recent droughts. While water use is projected to rebound, it is likely that a permanent reduction in per capita demand has occurred due to increased water-use efficiency and heightened water awareness. Development of the projected demand is presented in the following paragraphs.

Population Projections

Data on historical and projected population for the City of San Francisco have been estimated by the State Department of Finance (DOF) and the Association of Bay Area Governments (ABAG). This information was provided to Leedshill-Herkenhoff, Inc. (LH) by Tom Mullaney of the City Utilities Engineering Bureau (UEB). These population data are summarized in Figure 2-2. The City reached a peak population of approximately 775,000 about 1950. Population fell to about 680,000 around 1980. Current (1988) population is approximately 740,000. ABAG and DOF forecast a population of about the 1950 level by the year 2000.

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[4] College Hill, Lake Merced, Lombard, Merced Manor, McLaren Park, Stanford Heights, Sunset, Summit, Sutro, and University Mound.

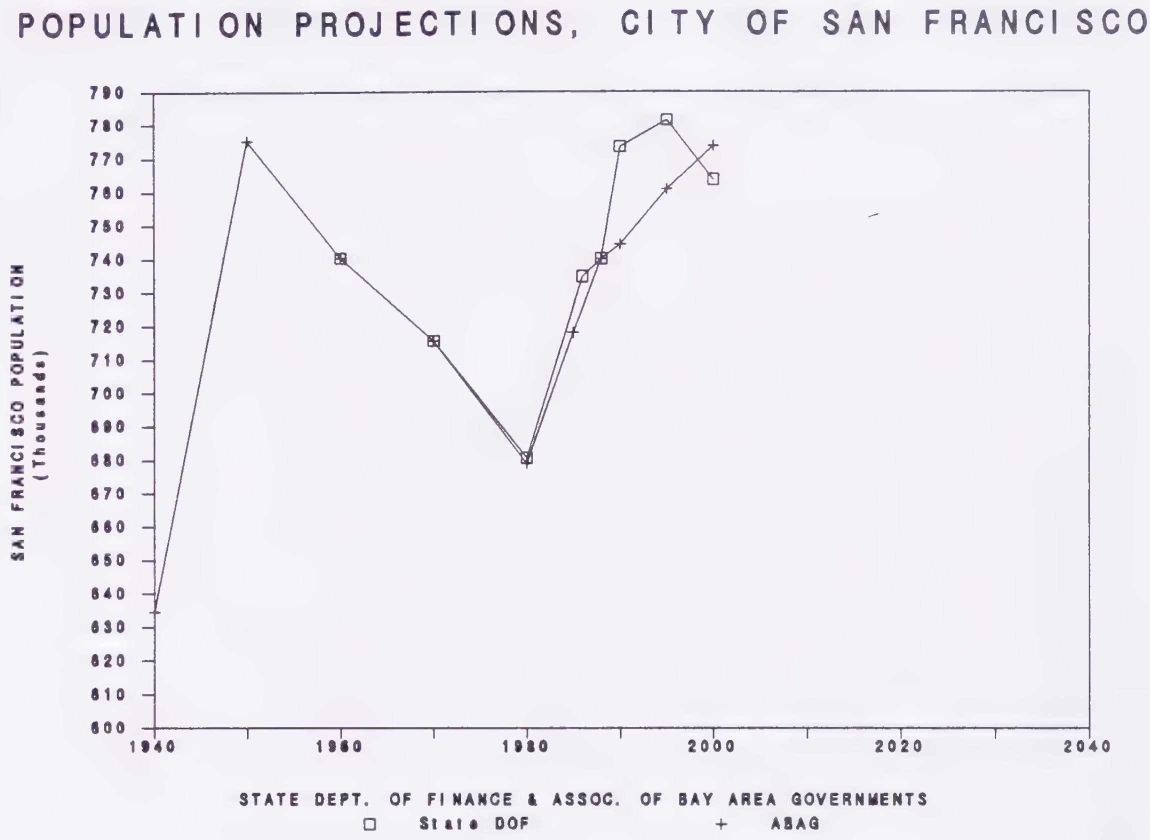

Figure 2-2

Water Use Projections

Data on historical water use were found in reports by DMJM, 1969[5], by WRA, 1986[6] and by CDM, 1989[7]. Each of these reports also provided estimates of projected City water use. These historical and projected water use data are summarized in Figure 2-3. Average water use was about 88 million gallons per day (mgd) in 1960, and peaked at about 107 mgd in 1975. The result of the 1976-77 drought is evident in these curves. Not only has actual consumption declined, but projected

5 Daniel, Mann, Johnson and Mendenhall, 1969, An Analysis of Water Demand, Supply, and System Improvements

6 Water Resource Associates, October 1986, Long-Term Water Demand Forecasts

7 Camp, Dresser & McKee, March 1989, Crystal Springs Water Treatment Plant Alternative

demand has been sharply reduced from that estimated in the 1969 DMJM report. Demand had declined to 88 mgd by 1980. Demand increased to about 96 mgd in 1985, and a slowly increasing trend is forecast.

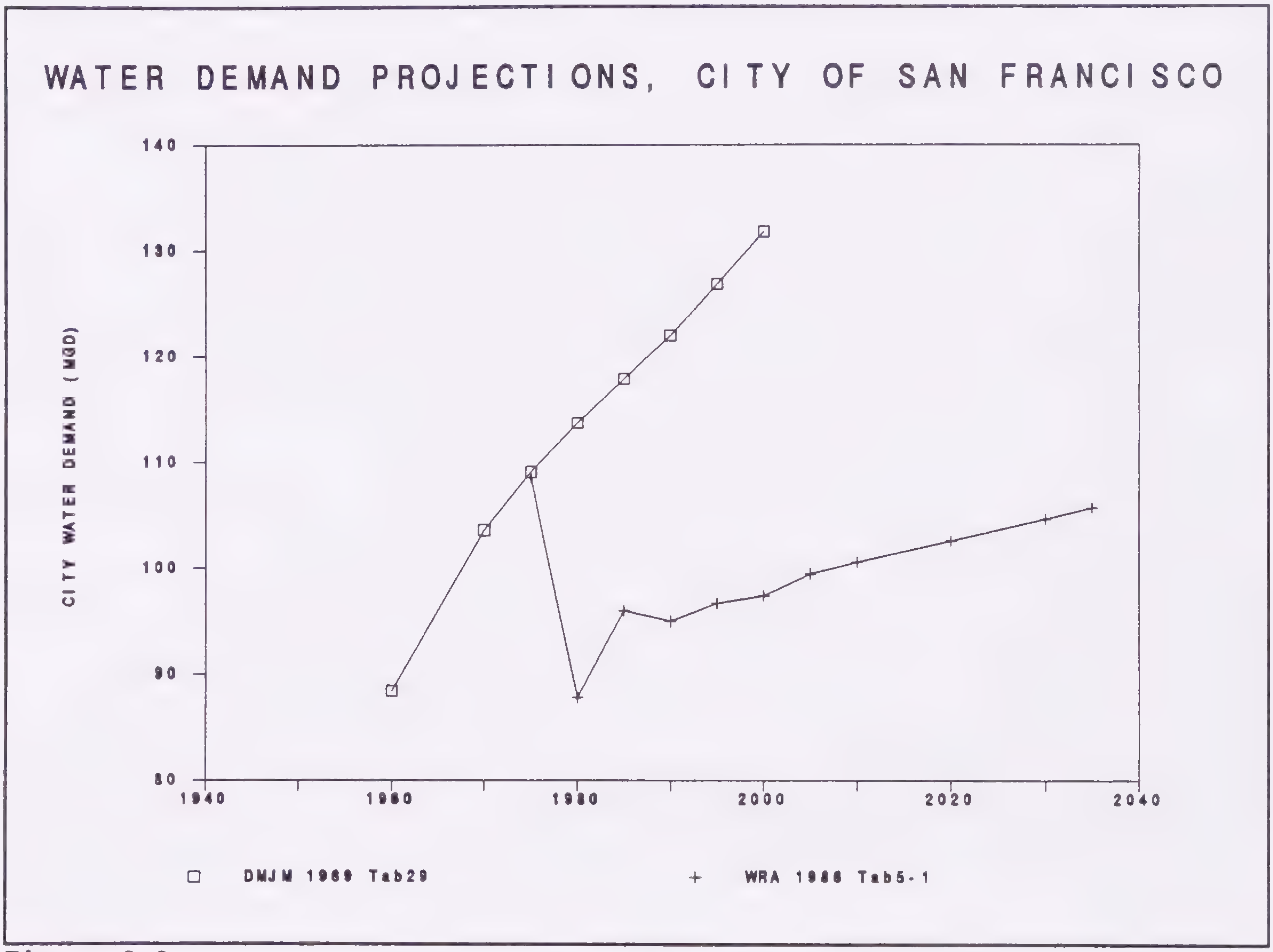

Figure 2-3

WRA performed a multiple regression analyses of historical water use parameters[8] to produce an estimate of future water use through the year 2035. Projections for these parameters are generally available through year 2005. Recognized trends were <u>extrapolated</u> by WRA to develop water usage to year 2035. Historical values for 1975 and 1980 were not used in the extrapolation since they were considered inconsistent with post-drought trends.

[8] Population, number of households, persons per household, employment, average household income, median household income, marginal price of water, marginal price of sewer, climatological, consumer price index.

The CDM report states that the 1977 drought lowered consumption by 30 percent. Use has not yet returned to the 1975 level.

Per Capita Water Use

Using the population and water demand data presented above, per capita water use was computed. Gross per capita use, about 120 gallons per capita-day (gpcd) in 1960, increased to about 150 gpcd in the early pre-drought 1970's. Per capita use has been about 130 gpcd in the 1980's. It is believed that this reduction in unit use will be permanent due to public awareness of water conservation, continued installation of less water-consumptive devices and fixtures, and from increases in water rates. The WRA projections suggest a trend toward 125 gpcd gross per capita use.

Ultimate City Demand

If the City population eventually grows to the 1950 level of 775,000 and per capita use continues to decline to 120 gpcd, ultimate City demand would be 93 mgd. If population increases 15 percent over present levels to about 850,000 and per capita use remains about 130 gpcd, ultimate demand of the City of San Francisco would be 110.5 mgd. Since the Balboa/Francisco Needs Assessment is considering permanent disposal of these possibly irreplaceable sites, use of a design ultimate demand of 110.5 mgd is considered prudent and was agreed upon by City staff for use in this study.

The 1989 CDM report used the WRA data supplemented and updated by flow measurement data and peaking factors provided by the San Francisco Water Department (SFWD). The Water Department provided CDM with water supply and consumption information for the years from 1970 through 1986. This information included metered maximum day flows and peak hour factors, and 24-hour diurnal flows for the maximum day flow recorded in fiscal years 1985-87.

The CDM projections were adjusted by CDM for weather-related demand and water conservation efforts.

DEMAND DISTRIBUTION

To evaluate the impact of incorporating Francisco and/or Balboa Reservoirs into the system, future City-wide demands were broken down by service areas. Demand distribution has been estimated by Pitometer Associates from measurements made from 1961 to 1988, by DMJM in 1969 and by CDM in 1989. Table 2-2 summarizes the distribution of City water use by pressure zone from each of the distribution estimates. This tabulation sums the distribution back to the source of supply; reference to the distribution schematic, Figure 2-1 may be helpful.

The Pitometer data in the summary have been computed as the average of numerous actual flow measurements made over a 28-year period. Each pressure zone was subdivided into several measurement districts, for which a few measurements were taken over the years. The Pitometer data thus provide a reasonable estimate of flow to the various pressure zones once individual district measurements are added together and averaged. Using this information for all of the pressure zones, the percentage of the total demand for each pressure zone was determined. These percentages were then applied to the estimated ultimate City demand of 110.5 mgd in order to estimate the 2035 demands for each pressure zone.

The methodology employed by DMJM is not known. However, the data appear to be closely related to the relative land area of the zones. If this is the case, land use and customer classification were ignored.

The CDM study developed the pressure zone distribution from a combination of metered flow data and reservoir fluctuation records taken over a 4-day period in July 1987. Several assumptions were necessary, and some of the resulting percentages are questionable. The CDM study focused on the Peninsula supply system, and the numbers thus developed may be close enough for those purposes. The Pitometer data have been adopted as the most reasonable for the purposes of this study. Applying the calculated percentages to the 110.5 mgd ultimate demand, year 2035 pressure zone average day demands are thus:

University Mound	36.5 mgd
Sunset	35.4 mgd
Lombard	3.3 mgd
College Hill	13.3 mgd

Table 2-2

Estimated Demand Distributions
Percentage of Total City Demand

	Pitometer 1961-88	DMJM 1969	CDM 1987
Pulgas Tunnel	100%	100%	100%
San Andreas Reservoir	20%	12%	45%
Baden-Merced pipeline	7%	5%	15%
Merced Manor Reservoir	2%	2%	5%
Central pump station	5%	2%	11%
54" San Andreas pipeline	13%	7%	30%
College Hill Reservoir	12%	7%	27%
Sunset Reservoir	1%		3%
Crystal Springs Bypass P/L	80%	88%	55%
60" C.S./U.Mound Res.	35%	25%	19%
60" Sunset/Lake Merced P/S	45%	63%	36%
Lake Merced P/S	10%	14%	12%
Sutro Reservoir	8%	10%	12%
Summit pump station	2%	4%	
60" Sunset pipeline	35%	49%	24%
Potrero Reservoir	1%		
Lombard Reservoir	3%		
Sunset Reservoir	31%	49%	24%
Total Sunset pressure zone	32%	49%	27%

FIRE FIGHTING DEMAND PROJECTIONS

Significant to the design and sizing of reservoir storage is provision of a fire fighting water supply. Determination of the fire reserve may be set by local policy, or may be determined by fire insurers. Both these sources have been reviewed for this study.

San Francisco is unique in that it possesses a high pressure fire supply system separate from the domestic supply system. This system is referred to as the Auxiliary Water Supply System (AWSS) or the High Pressure Supplementary System (HPSS). This system includes a dedicated, open-air, 10.5 MG reservoir at about elevation 800 feet on Twin Peaks, and an extensive grid of piping covering much

of the City. Other assorted tanks around the City connected to the high pressure system contain 25-30 MG available for fire demands. AWSS hydrants are large, and have red or blue tops. Domestic system hydrants have white tops.

The Fire Department also has six manifolds along the Embarcadero to allow pumping from the Bay. Diesel pumps are located at Van Ness and at Second and Townsend. Fire fighting demand of the October 17, 1989 Marina fire resulting from the earthquake was served by connecting the fireboat Phoenix to a portable fire system. Many domestic system water mains in the Marina District were damaged from the earthquake. Fire Chief Blackburn would like to have Francisco Reservoir renovated to provide emergency fire supply for the Marina District.

The SFWD reports two areas with low fire fighting pressures are Bernal Heights and Seacliff, both within the Sunset service area. The highest portions of Bernal Heights are served by a hydro-pneumatic pump station.

Fire Chief Blackburn of the San Francisco Fire Department (SFFD) was contacted in October 1989 to determine the Department's criteria. The Department has established the following general guidelines for required fire fighting flow rates and volumes:

- The domestic water system should be fully redundant to the AWSS.
- Residual pressures should be 20 psi or greater.
- Four-inch diameter mains should be eliminated.
- Fire demand should be sustainable for 12 hours.
- Fire-fighting flow rates to be met by general category of land use:

Downtown	12,000 gpm plus 6000 gpm secondary fire
Industrial	9000 to 12,000 gpm
Dense residential	6000 gpm (e.g. Western Addition)
Mercantile	4000 to 5000 gpm
Outer residential	2000 to 3000 gpm

The following additional criteria were applied by LH for the analysis:

- Fire fighting demand must be met during maximum day demand.
- Each pressure zone should, insofar as possible, be able to deliver the fire fighting flow rate without contributions from adjacent pressure zones. That is, opening divide valves to service fire demands should be minimized. Currently, SFWD crews are dispatched to operate divide valves at any fire of two alarms or more.

The SFWD City Distribution Division also provided LH with fire fighting flow rate requirements calculated by ISO Commercial Risk Services in April 1965. These requirements are listed in Table 2-3 by type of land use for various intersections throughout the three principal pressure zones. Where these 25-year-old data conflicted with the fire fighting flow rates listed by SFFD, the more severe requirement was used.

Table 2-3
Selected Fire Flow Requirements
Estimated by ISO Commercial Risk Services
April 1965

Land Use	Pressure Zone/ Intersection	Required Fire Flow (gpm)
	College Hill - 255	
Commercial	Geary/Taylor	12,000
Commercial	Market/Tenth	12,000
Commercial	McAllister/Hyde	5,000
Commercial	Ellis/Fillmore	3,500
Commercial	Fourteenth/Valencia	5,000
Commercial	Sixteenth/Sanchez	4,000
Industrial	Seventeenth/Vermont	4,000
Institutional	Tomkin/Banks	4,000
Residential	Twenty-eighth/Dolores	3,000
Residential	San Juan/Otsego	2,500
Residential	Burrows/Holyoke	2,500
	Sunset - 385	
Commercial	Point Lobos/Cliff House	4,000
Commercial	Geary/Twentieth	3,500
Commercial	Geary/Masonic	4,000
Commercial	Geary/Fillmore	4,000
Commercial	Irving/Twenty-ninth	3,500
Commercial	Irving/Ninth	3,500
Commercial	Ocean/Capitol	3,500
Commercial	Sacramento/Van Ness	5,000
Institutional	Balboa/Fifth	3,500
Institutional	Public Health Hospital	3,000
Institutional	S.F. State College	3,500
Residential	Sutter/Hyde	6,000
Residential	Buckingham/Nineteenth	3,000
Residential	Scenic/Twenty-sixth	2,500

Table 2-3 (cont.)
Selected Fire Flow Requirements
Estimated by ISO Commercial Risk Service
April 1965

Land Use	Pressure Zone/ Intersection	Required Fire Flow (gpm)
	University Mound - 172	
Commercial	Jackson/Sansome	12,000
Commercial	Pine/Kearney	12,000
Commercial	Minna/First	12,000
Commercial	Stevenson/Fifth	12,000
Commercial	Folsom/Third	12,000
Commercial	Northpoint/Hyde	4,000
Commercial	Chestnut/Scott	4,000
Commercial	Eighteenth/Mission	5,000
Commercial	Twenty-fourth/Mission	5,000
Industrial	Beach/Taylor	4,000
Industrial	Harrison/Eighth	4,000
Industrial	Fifth/Townsend	4,500
Industrial	Sixteenth/Third	5,000
Industrial	Twenty-second/Illinois	5,000
Industrial	Marin/Evans	5,000
Industrial	Evans/Third	5,000
Industrial	Evans/Jennings	4,000
Industrial	Dorman/Barneveld	4,000
Industrial	Sacramento/Van Ness	4,000
Industrial	Quesda/Griffith	3,000
Industrial	Paul/Third	3,500
Pier	Main/Embarcadero	6,000

Table 2-4 quantifies the amount of fire fighting storage volume thus required based on 12-hour fire fighting demand. Table 2-4 also demonstrates fire fighting volume based on a percentage of year 2035 average day demand by pressure zone.

Table 2-4

Required Fire Fighting Storage Volumes

Pressure Zone	Primary Fire (gpm)	Secondary Fire (gpm)	12-hour Volume (MG)	Equivalent Average Day Demand (days)
University Mound	12,000	6,000	12.96	0.4
College Hill	12,000	6,000	12.96	1.0
Sunset	8,000	---	5.76	0.2
Lombard	5,000	---	3.60	1.1
Francisco	4,000	---	2.88	---

* Required fire flow storage expressed in days of average daily demand for each pressure zone.

EMERGENCY STORAGE REQUIREMENTS

The purpose of an emergency storage reserve is 1) to provide water during emergencies for fire fighting, and 2) to provide a potable drinking water supply in the event of an interruption in water supply system deliveries.

According to San Francisco Fire Department (SFFD) guidelines, the domestic water system should be fully capable of meeting fire fighting demands. The Fire Department's Auxiliary Water Supply System (AWSS) supplements the domestic water system. In addition, under emergency conditions, non-potable fresh water or seawater can be introduced into the AWSS to meet fire fighting demands.

The City's water supply is virtually entirely imported from outside the City limits, and no groundwater reserve has yet been developed. Thus at this time the City is fully dependent on surface storage for its potable water supply.

Emergency Storage Criteria

A major emergency may entail not only loss of portions of the water supply plumbing, but in loss of the power supply to water treatment facilities and pump stations. For this study, two criteria are applied for emergency storage within the City: First, only potable water is considered part of the emergency supply; Second, although SFWD has in place,or is constructing, emergency stand-by power facilities at major treatment plants and pumping stations, only water provided by gravity flow is considered reliable. The quantity of water in reserve storage is further constrained to that amount that can be circulated on a regular basis to avoid stagnation. The SFWD Water Quality Division reports that reservoirs must be circulated at least every seven days to avoid objectionable taste and odors.

The quantity of water to be stored in local reservoirs for emergency reserve supplies is largely a policy decision based on the nature of the emergency and its impact on the water supply system. The City currently has storage equivalent to 3.5 days of average day demand. For comparison, the East Bay Municipal Utilities District (EBMUD) provides emergency storage equal to 2.6 days of average day demand. Emergency tie-ins to adjacent water systems, an option available to other utilities, are not possible due to San Francisco's geographical location at the end of a peninsula.

Selection of Design Emergency

Approximately 26 billion gallons of untreated water storage capacity is available in Crystal Springs, San Andreas, and Pilarcitos Reservoirs on the Peninsula, serving both the City and Peninsula communities. There is 2.9 billion gallons of storage capacity within the City, of which 2.5 billion gallons is non-potable water stored in Lake Merced. Only 0.4 billion gallons is potable water located within the City.

There are two critical portions of the water supply system which could isolate the City from its source of supply: 1) The Irvington Tunnel, which passes through the Coast Range and Calaveras fault zone, and links the eastern Hetch Hetchy system and Calaveras and San Antonio Reservoirs to the Bay Area; and 2) Major water supply facilities on the Peninsula, including the Pulgas Tunnel and San Andreas Treatment Plant adjacent to the San Andreas Fault, and the Crystal Springs, San Andreas, and Sunset pipelines which in places share a narrow right-of-way. The shared right-of-way raises the possibility that failure of one pipeline could potentially damage the others. It is these Peninsula facilities that are the critical link in the City's water supply system, as discussed below.

Assuming full reservoirs, there is about eight months of Bay Area storage at current City and Peninsula system-wide average daily use of about 300 mgd. If the Irvington Tunnel were to fail, only the Crystal Springs, San Andreas, and Pilarcitos Reservoirs would remain connected to the distribution system. These west-of-the-tunnel reservoirs contain about one-third of the Bay Area storage capacity, and serve service areas in the City and Peninsula. Assuming these reservoirs are full, several months of storage is still available in case of tunnel failure. Hydraulic characteristics of the system would limit the ability to deliver water to portions of the South Bay.

Because water storage on the Peninsula is very large, supply interruptions upstream of the Pulgas Tunnel will not affect water supply to the City. The City water supply could be provided entirely from San Andreas Reservoir and San Andreas Water Treatment Plant during any interruption in the Hetch Hetchy, South Bay, or Peninsula systems. The capacity of the San Andreas Water Treatment Plant is currently being upgraded to 120 mgd, and will be expanded again to a capacity of 180 mgd. This capacity is sufficient to meet the combined average demand of both the City and north Peninsula.

More critical to the City is the potential failure of Peninsula facilities that could preclude delivery of water across the County line. The Peninsula transmission system has numerous redundancies incorporated which permit water deliveries in case of the failure of a single facility. However, it is prudent to plan emergency storage reserves based on the conceivable worst-case emergency: multiple or complete conveyance system failure. Three principal types of system

failure have been considered in selection of the design emergency: 1) Failure of PG&E or back-up power sources; 2) Loss of conveyance facilities from the Pulgas Tunnel to the Baden Pump Station; and 3) Loss of conveyance facilities from the Baden Pump Station to the County line.

Loss of electrical power will not significantly curtail water deliveries across the County line due to the availability of alternative water conduits and back-up power supplies. Gas turbine stand-by power generators will allow pumping and treatment operations to continue at the San Andreas Water Treatment Plant. Even if this back-up were to fail, gravity flow of up to 100 mgd of disinfected, unfiltered water can be bypassed around the plant in severe circumstances where water quality became a secondary concern. Electrical power failures will not affect deliveries through the gravity-fed Crystal Springs pipelines, which have a capacity to supply the City with up to 105 mgd, more than the current average City use. Within the City, Lake Merced Pumping Station has full stand-by power. Alemany Pump Station currently does not have stand-by power. Smaller pump stations, generally serving the higher-elevation pressure zones, can be powered by mobile generator units.

North of the Pulgas Tunnel to the Baden Pump Station there is considerable interconnection and redundancy of the water transmission network. Loss of a single pipeline in this reach will not decrease supply to the City. Capacity loss from total failure of <u>either</u> the "high zone" San Andreas and Sunset Supply pipeline group <u>or</u> the "low zone" Crystal Springs pipeline group can be mitigated by use of the undamaged group. These two pipeline groups are interconnected at the Baden Pump Station, permitting normal delivery routes across the County line to City terminal reservoirs.

From the Baden Pump Station north to the terminal reservoirs within the City, there are five separate supply lines.[9] Various combinations of out-of-service pipelines would result in varying levels of supply deficiencies. Use of the Crosstown Pipeline can compensate for failure of any one line by cross-feeding by gravity from Sunset Reservoir or from University Mound Reservoir via the

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9 The Sunset Supply Pipeline, San Andreas Pipelines No. 2 and No. 3, and Crystal Springs Pipelines No. 2 and No. 3.

Alemany Pump Station. A further discussion of these options is presented in Chapter 4 "Source Interruption or Storage Out of Service". The worst-case scenario is for all five supply mains to be out of service simultaneously. Such a scenario is possible since the four largest pipelines share a common right-of-way in the vicinity of the Baden Pump Station. Rupture of one pipeline could potentially damage the others. Although such an event is unlikely, it should be considered in determining in-City storage needs. In fact, the January 18, 1990 failure of San Andreas No. 3 Pipeline occurred at exactly this location with no damage to neighboring pipelines. However, emergencies caused by a major earthquake or a pipeline failure and subsequent wash-out of adjacent pipelines could isolate the City from the source of supply for a significant period. For the purposes of this report, a complete failure of the water supply system south of the County line has been adopted as the conceivable worst-case design emergency.

Under such emergency conditions, partial restoration of service or arrangements for temporary emergency facilities could require one to two weeks, and thus an emergency storage reserve adequate for that duration of time would be required. It is reasonable to assume, however, that under such emergency conditions extreme rationing measures would be implemented. For the purposes of this report, it is assumed that domestic water use during the period immediately following a major catastrophe would be restricted to 50 percent or less of normal usage. Therefore, for the purposes of this report, provision of from three and one-half to seven days of normal usage (seven to fourteen days of rationed usage) of storage has been adopted as a goal for the emergency storage reserve.

Stating emergency storage reserves another way,

emergency storage of 3.5 days @ average usage = a 7-day supply @ 50% rationing
emergency storage of 7.0 days @ average usage = a 14-day supply @ 50% rationing

Provision of an emergency storage reserve equal to 3.5 to 7.0 days of average usage has been adopted as a goal to meet the water demands during the conceivable worst-case emergency.

Evaluation of Existing Storage

City-wide, there is 2.9 billion gallons of water storage capacity, of which non-potable Lake Merced comprises 2.5 billion gallons. Recognizing that in-City reservoirs are generally operated at from 80 percent to 100 percent of capacity, the other 0.4 billion gallons of potable, gravity-flow storage is presently adequate to provide 3.5 days of emergency reserve. As illustrated in the following tabulation, this reserve will decline to 3.0 days of storage under ultimate (year 2035) demand conditions, which is less than the storage criteria established in the previous section.

	Existing Emergency Reserve (days of average demand)	
	Reservoirs 80% Full	Reservoirs Full
Average City-wide potable water storage		
at present demand	3.5 days	4.4 days
at ultimate demand	3.0	3.8

Table 2-5 lists the storage reserve for reservoirs within the City. In this table, large reservoirs are grouped together with other reservoirs which could be supplemented by gravity flow. Thus, although Potrero, Lombard and College Hill Reservoirs individually have one day or less of storage reserve, supplemental supply from Sunset Reservoir provides an average reserve of 2.9 days [10].

Although additional water can normally be delivered to College Hill or Sunset Reservoirs from the University Mound Reservoir via the Alemany Pump Station, this electrically-powered pump station is not equipped with a source of emergency power, and is thus not considered part of the emergency supply available to College Hill or Sunset Reservoirs.

[10] University Mound Reservoir can also be supplemented by the Sunset group through the Crosstown Pipeline.

Table 2-5

Existing Reserve Supply by Pressure Zone

Pressure Zone	2035 Average Demand (mgd)	Pressure Zone Storage (MG)	Emergency Supply (days) Reservoirs 80% Full	Reservoirs Full
Summit Group				
Summit	2.2	14.70 /1	5.3	6.7
Sutro	8.8	31.40	2.8	3.6
	11.1	46.10	3.3	4.2
Stanford Heights	5.5	12.98 /2	1.9	2.3
Sunset Group				
Sunset	35.4	176.78 /3	4.0	5.0
Potrero	1.1	1.10	0.8	1.0
Lombard	3.3	2.70	0.7	0.8
Merced Manor	2.2	9.50	3.4	4.3
College Hill	13.3	13.50	0.8	1.0
	55.3	203.58	2.9	3.7
University Mound	36.5	150.00 /4	3.3	4.1
Treasure Island	2.2	6.50 /5	2.4	2.9
	110.5	419.15	3.0	3.8

/1 Forest Knolls(0.1)+Summit(14.0)+Forest Hill(0.6)
/2 Stanford Heights(12.9)+Mt. Davidson(0.075)
/3 Sunset(176.7)+Lincoln Park(0.075)
excludes Laguna Honda(44.0)
/4 U.Mound (140.9)+Hunters Point(1.1)+McLaren Park(8.0)
excludes Francisco(2.5)
/5 Treasure Island is also connected to EBMUD.

Additional Storage Potential

Table 2-6 illustrates that addition of a single Balboa basin would increase the emergency storage of Merced Manor, College Hill, and University Mound Reservoirs to 3.8 days. Unburdened of supplying Merced Manor and College Hill Reservoirs, the storage of the Sunset group increases to 3.6 days.

Table 2-7 shows that if both Balboa basins are used, an average of 5.0 days of emergency storage would be available to Merced Manor, College Hill, and University Mound pressure zones. As noted above, supplying this reservoir group from Balboa unburdens the Sunset group of reservoirs, thus increasing its effective reserve.

University Mound Reservoir can supply the 36.5 mgd year 2035 average day demand for 3.3 days when 80% full. This computes to approximately 1.5 million gallons of storage required for each hour of emergency supply to the University Mound pressure zone. Francisco Reservoir storage is relatively small compared to the total University Mound demand. As shown in Table 2-8, a moderately-sized 5.8-MG Francisco Reservoir would provide only four hours (0.2 days) of emergency supply. However, relative to the 2.2 mgd demand in the Marina District, a 5.8-MG Francisco Reservoir could provide 2.1 days of storage in addition to the 3.3 days provided by University Mound, if Francisco is plumbed to serve the Marina alone. Since the Marina District is remote from the source of supply, such local storage would be valuable in the event of a major catastrophe.

Table 2-6

Use of One Balboa Reservoir Basin
to increase Emergency Storage

Pressure Zone	2035 Average Demand (mgd)	Pressure Zone Storage (MG)	Emergency Supply (days) Reservoirs 80% Full	Emergency Supply (days) Reservoirs Full
Summit Group				
Summit	2.2	14.70 /1	5.3	6.7
Sutro	8.8	31.40	2.8	3.6
	11.1	46.10	3.3	4.2
Stanford Heights	5.5	12.98 /2	1.9	2.3
Sunset Group				
Sunset	35.4	176.78 /3	4.0	5.0
Potrero	1.1	1.10	0.8	1.0
Lombard	3.3	2.70	0.7	0.8
	39.8	180.58	3.6	4.5
Balboa Group (one basin)				
Balboa		75.00		
Merced Manor	2.2	9.50	3.4	4.3
College Hill	13.3	13.50	0.8	1.0
University Mound	36.5	150.00 /4	3.3	4.1
	51.9	248.00	3.8	4.8
Treasure Island	2.2	6.50 /5	2.4	2.9
	110.5	494.15	3.6	4.5

/1 Forest Knolls(0.1)+Summit(14.0)+Forest Hill(0.6)
/2 Stanford Heights(12.9)+Mt. Davidson(0.075)
/3 Sunset(176.7)+Lincoln Park(0.075)
excludes Laguna Honda(44.0)
/4 U.Mound (140.9)+Hunters Point(1.1)+McLaren Park(8.0)
excludes Francisco(2.5)
/5 Treasure Island is also connected to EBMUD.

Table 2-7

Use of Both Balboa Reservoir Basins
to increase Emergency Storage

Pressure Zone	2035 Average Demand (mgd)	Pressure Zone Storage (MG)	Emergency Supply (days) Reservoirs 80% Full	Emergency Supply (days) Reservoirs Full
Summit Group				
Summit	2.2	14.70 /1	5.3	6.7
Sutro	8.8	31.40	2.8	3.6
	11.1	46.10	3.3	4.2
Stanford Heights	5.5	12.98 /2	1.9	2.3
Sunset Group				
Sunset	35.4	176.78 /3	4.0	5.0
Potrero	1.1	1.10	0.8	1.0
Lombard	3.3	2.70	0.7	0.8
	39.8	180.58	3.6	4.5
Balboa Group				
Balboa (both basins)		150.00		
Merced Manor	2.2	9.50	3.4	4.3
College Hill	13.3	13.50	0.8	1.0
University Mound	36.5	150.00 /4	3.3	4.1
	51.9	323.00	5.0	6.2
Treasure Island	2.2	6.50 /5	2.4	2.9
	110.5	569.15	4.1	5.2

/1 Forest Knolls(0.1)+Summit(14.0)+Forest Hill(0.6)
/2 Stanford Heights(12.9)+Mt. Davidson(0.075)
/3 Sunset(176.7)+Lincoln Park(0.075)
excludes Laguna Honda(44.0)
/4 U.Mound (140.9)+Hunters Point(1.1)+McLaren Park(8.0)
excludes Francisco(2.5)
/5 Treasure Island is also connected to EBMUD.

Table 2-8

Use of Francisco Reservoir
to increase Marina District Emergency Supply

Pressure Zone	2035 Average Demand (mgd)	Pressure Zone Storage (MG)	Emergency Supply (days) Reservoirs 80% Full	Reservoirs Full
Existing Facilities				
University Mound				
Marina District	2.2	9.08 /1	3.3	4.1
Remainder	34.3	140.92 /1	3.3	4.1
Total University Mound	36.5	150.00 /2	3.3	4.1
Total City	110.5	419.15	3.0	3.8
With 5.8 MG Francisco Reservoir				
University Mound				
Marina District	2.2	14.88 /3	5.4	6.7
Remainder	34.3	140.92 /1	3.3	4.1
Total University Mound	36.5	155.80 /2	3.4	4.3
Total City	110.5	424.95	3.1	3.8
One Balboa basin and 5.8 MG Francisco				
Balboa Group				
Balboa (both basins)		75.00		
Merced Manor	2.2	9.50	3.4	4.3
College Hill	13.3	13.50	0.8	1.0
University Mound				
Marina District	2.2	14.88 /3	5.4	6.7
Remainder	34.3	140.92 /1	3.3	4.1
Total University Mound	36.5	155.80 /2	3.4	4.3
Total Balboa Group	52.0	253.80	3.9	4.9
Total City	110.5	499.95	3.6	4.5
Both Balboa basins and 5.8 MG Francisco				
Balboa Group				
Balboa (both basins)		150.00		
Merced Manor	2.2	9.50	3.4	4.3
College Hill	13.3	13.50	0.8	1.0
University Mound				
Marina District	2.2	14.88 /3	5.4	6.7
Remainder	34.3	140.92 /1	3.3	4.1
Total University Mound	36.5	155.80 /2	3.4	4.3
Total Balboa Group	52.0	328.8	5.1	6.3
Total City	110.5	574.95	4.2	5.2

/1 Pressure zone storage proportional to demand.
/2 U.Mound (140.9)+Hunters Point(1.1)+McLaren Park(8.0)
/3 5.8 MG Francisco plus U.Mound storage proportional to demand.

Emergency Storage Summary

The conceivable worst-case design emergency is a cut-off of all supplies south of the County line. Partial restoration of service would take one to two weeks, during which time extreme rationing of 50% or more would be in effect. It is therefore prudent to provide storage of one-half to one full week of normal usage (one to two weeks of rationed usage) to meet City demands.

City reservoirs are typically operated at from 80 percent to 100 percent of capacity. Table 2-9 illustrates that at 80 percent capacity no pressure zone group provides even one-half week (3.5 days) of reserve storage under average year 2035 demand. Total City reserves average 3.0 days.

Table 2-9

Summary of Emergency Storage Reserve
Reservoirs Drawn Down to 80% of Capacity

Pressure Zone	Emergency Supply with Reservoirs 80% Full 1/ (days of average year 2035 demand)				
	Present System	One Balboa Basin	Two Balboa Basins	5.8-MG Francisco	One Balboa Basin plus Francisco
Summit	3.3 *	3.3 *	3.3 *	3.3 *	3.3 *
Sutro	3.3 *	3.3 *	3.3 *	3.3 *	3.3 *
Stanford Heights	1.9 *	1.9 *	1.9 *	1.9 *	1.9 *
Sunset	2.9 *	3.6	3.6	2.9 *	3.6
Potrero	2.9 *	3.6	3.6	2.9 *	3.6
Lombard	2.9 *	3.6	3.6	2.9 *	3.6
Merced Manor	2.9 *	3.8	5.0	2.9 *	3.8
College Hill	2.9 *	3.8	5.0	2.9 *	3.8
University Mound					
Marina District	3.3 *	3.8	5.0	5.4	5.9
Remainder	3.3 *	3.8	5.0	3.3 *	3.8
Total University Mound	3.3 *	3.8	5.0	3.4 *	3.8
Treasure Island	2.4 **	2.4 **	2.4 **	2.4 **	2.4 **
Total City	3.0 *	3.6	4.1	3.1 *	3.6

* Does not meet emergency storage criteria.
** Also supplied by EBMUD.
1/ Storage averaged by Reservoir groups with gravity-flow cross connections.

The addition of a single Balboa basin would provide an average of 3.6 days of storage to those pressure zones sharing gravity-flow storage with Sunset Reservoir (Sunset, Potrero, and Lombard Reservoirs), and would increase storage to pressure zones gravity-fed by Balboa Reservoir (Merced Manor, College Hill, and University Mound Reservoirs) to an average of 3.8 days. Total City storage reserves would average 3.6 days.

The addition of both Balboa Reservoir basins would also increase the storage of the Sunset group to 3.6 days, while increasing the storage of the Balboa group to 5.0 days. City-wide storage would average 4.1 days with both Balboa basins.

A 5.8-MG Francisco Reservoir used to serve a new pressure zone in the Marina District would provide 5.4 days of emergency storage to the Marina in conjunction with University Mound Reservoir.

Addition of Balboa or Francisco Reservoirs would not increase potable, gravity-flow reserves of Summit, Sutro, Stanford Heights, or Treasure Island[11] pressure zones. However, each could benefit from additional storage under less catastrophic emergencies if pumping plants remained in service.[12]

OPERATIONAL CRITERIA

Present System Operation

The water distribution system for the areas considered in this study are gravity flow, not pump pressurized. In general, reservoirs are drafted each day and are allowed to refill each night. The system is operated manually and has a minimum of telemetry or remote control devices. High pressure zones are cross-connected to low pressure zones through gate valves called "spill points" or "divide valves". At any fire of two alarms or more, SFWD crews are dispatched to operate divide valves. When divide valves are open or throttling, pressures are

[11] Treasure Island is also supplied by a connection to EBMUD.

[12] Many City pump stations have a source of stand-by power supply, and additional stand-by capacity is included in the City capital improvement program. Smaller pumping stations, generally serving the higher-elevation pressure zones, can be powered by mobile generator units.

monitored at adjacent hydrants. Other low pressure problems may also be remedied by opening divide valves from a zone of high pressure to the deficient zone.

Water is delivered to Sunset Reservoir from the Lake Merced Pump Station and from the San Andreas Water Treatment Plant. The southern portion of the Sunset distribution system is connected to the gravity-flow San Andreas pipeline. This pipeline is often throttled at the San Pedro valve lot to balance Sunset Reservoir pressure. During demand periods, little if any San Andreas water flows to Sunset Reservoir. Rather, the San Andreas water directly serves the southern parts of the Sunset pressure zone, and serves the College Hill zone after being reduced in pressure at the Roanoke PRV station.

The City currently employs only a handful of pressure reducing stations as incorporating pressure reducing valves (PRV's) is viewed as energy wasteful. One pressure reducing station located at Arlington and Roanoke Streets takes water at Sunset pressure and reduces the pressure for supply to the College Hill pressure zone. A typical recorder chart was obtained for the week of October 20-27, 1989. This chart shows downstream pressures are between 46 and 52 psi. The elevation of the PRV is about 175 feet. Thus, the downstream hydraulic gradeline is maintained between about 280 to 295 feet. Recorded daytime pressures upstream of the PRV are about 60 psi (315 feet), with nighttime peaks of about 80 psi (360 feet). These pressures would indicated that water from this pipeline would not reach the Sunset Reservoir (a pressure of about 90 psi at Roanoke Valve Vault is needed to reach Sunset).

During a field trip to the Roanoke Valve Vault, Leedshill-Herkenhoff engineers were shown an alternative gage that read 10 psi higher than the pressure chart. If the pressures are indeed 10 psi higher, then it is possible for water to flow into Sunset Reservoir during the early morning hours when the recording gage reads roughly 80 psi.

Water may also flow from Sunset reservoir through the 54-inch San Andreas pipeline and into the Crosstown pipeline toward College Hill.

Recommended Design and Operation Criteria

The following criteria have been adopted for this study:

- **Minimum/maximum pressures:** City staff report that existing pressures are generally between 30 and 130 psi, with some areas as high as 160 psi, and others with low pressures during fire-fighting flow conditions. Adopted pressure criteria for this study will be to keep water pressures between 40 to 90 psi under normal conditions, except for possible small, isolated spots with traditionally low pressures where 30 psi shall be acceptable. Residual system pressures during a fire should be at least 20 psi. Insofar as possible, each pressure zone should be capable of handling the full fire demand, without opening divide valves.

- **Unit Headloss:** Insofar as practical, headloss in the distribution system shall be limited to a maximum of 5.0 feet per 1000 feet of pipe length.

- **Maximum velocity:** Pipe velocities shall be less than 10 feet per second to minimize headloss and to minimize damage to valve seats.

- **Pipe "C" factors:** The City is involved in an on-going program of mortar lining all mains 20 inches in diameter and larger. For the modeling of the system under ultimate demands, it was assumed that this program had been completed[13]. City staff report that the mortar lining is about one-eighth to one-quarter inch in thickness. Therefore, the diameter of the pipe is not appreciably effected and the nominal diameter of pipe is used for velocity calculations and modeling. A smooth mortar lining will have a Hazen-Williams "C"-factor roughness of 120 to 130. To account for valves, elbows, tees, and aging of the lining, a C-factor of 110 was used in the modeling effort for pipes 20 inches in diameter and larger.

  For smaller pipes, pipe roughness factors were taken from measured Pitometer Associates data, and from theoretical curves provided by the

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13 Of the large diameter transmission mains from the Peninsula, only the 54-inch San Andreas No. 2 pipeline has yet to be lined.

City. These data have been analyzed by pipe material, diameter and age. Pipe materials and ages have been determined from City records.

- **Seismic load:** Seismic design is based on the maximum credible earthquake.

Peak water demands such as maximum day, peak hour, and fire-flow requirements play an important role in the design of distribution and storage facilities since these conditions dictate the most critical conditions. Maximum day and peak hour demands are normally denoted by "peaking factors" which are ratios of the peak demands to the average annual demand.

- **Maximum day demand factor**. Table 2-10 presents estimates from previous studies of maximum day demands as a percentage of the average day demand. CDM analyzed data from 1975 through 1985 in determining the overall maximum day factor. Percentages throughout this period remained fairly uniform. DMJM analyzed data from 1966 and adjusted the factors after comparison with previous years. It was determined that temperatures south of the City had an effect on the peak day demand. East Bay Municipal Utility District (EBMUD) uses a maximum day factor of 170 percent of average day for areas west of the Berkeley/Oakland hills. For this study, a 150 percent ratio of maximum day to average day demand was agreed upon by City staff and is used for all pressure zones.

- **Peak Hour Demand**. Peak hour factors as a percentage of the average day demand use are shown in Table 2-11. A 225 percent ratio of peak hour demand to average day demand was agreed upon and is used for all pressure zones.

SUMMARY

Taken together, University Mound, Sunset, and College Hill pressure zones account for 80 percent of total City water demand. A portion of the University Mound service area was formerly supplied by Francisco Reservoir. Balboa Reservoir is located adjacent to the Crosstown pipeline connecting Sunset and College Hill Reservoirs, and is at an elevation intermediate to these reservoirs.

Table 2-10

Maximum Day Factors by Pressure Zone
Percent of Average Day

Service Area	CDM	DMJM 1966	DMJM Adjusted*	City Estimate
City of San Francisco	125%	148%	160%	150%
University Mound	---	148%	160%	
Sunset	---	149%	160%	
College Hill	---	160%	160%	
Lombard	---	---		
Balboa	---	---		

* Adjusted for temperature and inadequate pressures.

Table 2-11

Peak Hour Demands by Pressure Zone
Percent of Average Day Demand

Service Area	CDM	DMJM	Pitometer*	City Model
City of San Francisco	141%			
University Mound		260%	168%	225%
Sunset		210%	171%	225%
College Hill		280%	165%	
Lombard			180%	

* Percentages for the Pitometer measurements were taken as the maximum peak hour demand of several random measurements.

The Crystal Springs Bypass supplies University Mound pressure zone by gravity and Sunset Reservoir via the Lake Merced Pump Station. Bypass water is pumped through a lift of about 34 feet to the 335-foot elevation Crystal Springs Balancing Reservoir under some flow conditions, but is reduced to elevation 305-foot pressure before re-entering the system. Filtration is not currently required for the Bypass water, but treatment will be required in the future.

College Hill Reservoir is supplied by gravity from the San Andreas Water Treatment Plant finished water reservoir after treatment. Water is lifted from Crystal Springs Reservoir over 160 feet to reach the finished water reservoir. Water from San Andreas also supplies the southern portion of the Sunset pressure zone. Pressures are reduced at the Roanoke PRV station to serve College Hill pressure zone.

No water quality problems have been reported. Water passing through the open-air Crystal Springs and San Andreas Reservoirs to College Hill and Sunset pressure zones is treated at the San Andreas Water Treatment Plant. Direct Hetch Hetchy service to Sunset and University Mound pressure zones requires only chlorination, but current regulations may require treatment in the future.

Water use in the City of San Francisco averaged about 96 mgd in 1985. City-wide average day water demand is estimated to increase to 110.5 mgd by the year 2035. This demand has been adopted as the ultimate City demand for planning purposes. Of this total, 36.5 mgd will be required in the University Mound pressure zone, 13.3 mgd in the College Hill zone, and 35.4 mgd in the Sunset zone. In addition, Sunset also requires 4.4 mgd to service its satellite Reservoirs, Lombard and Potrero (3.3 and 1.1 mgd, respectively).

College Hill and Lombard Reservoirs do not have sufficient storage to satisfy fire fighting reserve requirements. Both are dependent on Sunset Reservoir for supplementary supplies. The area previously served by Francisco Reservoir is now served by University Mound. The SFFD considers Francisco's location, remote from the source of supply and adjacent to the Marina and North Beach Districts, invaluable as a fire reserve facility. Francisco could also be a secondary supply source to fight a Downtown fire. A report by Cornell University (O'Rourke, 1985) notes that water mains in the University Mound pressure zone serving Downtown cross areas of random fill where numerous breaks are likely.

Current City-wide storage reserves average 3.5 days of average use. This reserve will decline to 3.0 days under ultimate, year 2035 demands. A major emergency could cut off water supplies for one to two weeks. Assuming strict rationing, existing consumption could be cut in half. San Francisco's position at the end of a peninsula does not allow the possibilities for emergency tie-ins to adjacent

systems that other utilities may have. A goal of three and one-half to seven average days of emergency, gravity-flow potable water storage has been adopted. Additional storage is required to meet this goal. Addition of one Balboa basin would boost emergency reserves of College Hill, University Mound, and Merced Manor Reservoirs to 3.8 days, from 2.9, 3.3 and 2.9 days, respectively. Use of both basins would increase the emergency reserve of these reservoirs to 5.0 days. Unburdened of the need to supply College Hill and Merced Manor, Sunset Reservoir and its satellite Reservoirs would go from 2.9 days of storage to 3.6 days. Use of the existing or enlarged Francisco Reservoir increases University Mound storage by only a few hours, but would add 2.1 days of local storage to meet Marina District demands.

Identified Existing Deficiencies

The following are known system deficiencies noted in the initial portion of this study by City staff or by LH engineers. Additional conveyance system deficiencies are determined as part of the modeling effort described in Chapter 4.

- There are areas of persistent low pressures in the Western Addition and Chinatown in the northern portions of the College Hill pressure zone.

- The Sunset pressure zone has areas of high pressures in the Richmond District, and east of Twin Peaks.

- Fire fighting storage reserves are deficient in the College Hill and Lombard pressure zones.

- There is inadequate fire fighting storage for the Marina District. Numerous water main breaks in the Marina District from the October 1989 earthquake required an emergency pipeline system to be installed, and seawater pumped from the Bay to fight a major fire.

- Several pressure zones are apparently unable to provide adequate fire fighting pressures. At any fire of two alarms or more, SFWD crews are dispatched to operate divide valves from higher pressure zones.

- SFWD reports low fire fighting pressures in Bernal Heights and Seacliff, both within the Sunset service area.

- Three and one-half to seven days of potable, gravity-flow reserve storage may be required in a major emergency. Under current demands, there are 3.5 days of storage at average demands. As demand continues to grow, this reserve will decline to 3.0 days of storage under ultimate demand.

Areas experiencing low pressures in the College Hill pressure zone could benefit from the higher elevation Balboa Reservoir would provide. Furthermore, service from Balboa could relieve high pressures in the higher Sunset zone. Current storage reserves available to meet emergency demands are inadequate in all pressure zones. Addition of one, or both, Balboa Reservoir basins would provide significant additional storage. Additional storage in the Marina District would be beneficial. Renovation of Francisco Reservoir would provide this storage.

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CHAPTER 3
STRUCTURAL AND GEOTECHNICAL CONSIDERATIONS

GENERAL

LH, Inc./AGS, Inc. have evaluated the structural and geotechnical conditions for the proposed Balboa and Francisco reservoirs based on a review of existing data and site visits. The data reviewed and the results of the evaluation are presented for each site in separate sections below. Certain regional data applicable to both sites, such as regional geology and seismicity, are presented only in the discussion of Balboa Reservoir.

BALBOA RESERVOIR

Site Conditions

The Balboa Reservoir site consists of two existing cut and fill basins developed on the gentle south facing slope of a small, broad, west-draining valley. The land rises from the site northward to the San Miguel Hills and eastward to City College hill. Elevations range from about 205 feet, below the toe of the south basin, to about 320 feet, above the rim of the north basin.

Both basins are lined with asphalt concrete and the exterior slopes are covered with vegetation. No outcrops of geologic units underlying the facility were observed during the site reconnaissance.

Geologic Conditions

Balboa Reservoir is located in the south central portion of the City of San Francisco on the San Francisco Peninsula. The peninsula is part of the Coast Ranges geomorphic province which is characterized by northwest trending mountains and valleys, and is dominated by northwest trending faults and other structures. Much of the peninsula is underlain by the late Mesozoic age rocks of the Franciscan Complex. Tertiary and Quaternary formations occur locally in profound unconformity on the Franciscan, while other Mesozoic formations occur in fault contact with the Franciscan Complex.

The reservoir is situated on Colma Formation, a Pleistocene age, unconsolidated sandy estuarine and coastal deposit (Bonilla, 1971). The Colma consists of horizontally bedded, medium to coarse sand with as much as 15 to 20 percent fines, and includes occasional lenses and beds of silt or clay. Clayey and sandy clay layers were reportedly encountered beneath the southeast corner of the south basin during an early site investigation.

Franciscan Complex underlies the Colma Formation beneath Balboa Reservoir and crops out to the east on City College hill. The depth to Franciscan increases to the southwest, and may be on the order of 200-250 feet beneath the southwest corner of the south basin.

Seismicity and Faulting

The reservoir site is within a seismically active region and most of the earthquake activity is coincident with major faults in the region.

The five largest earthquakes experienced in the Bay Area, their fault sources and dates of occurrence are presented in Table 3-1.

Table 3-1
Historical Earthquakes

Date	Estimated[1] Magnitude	Fault
June 10, 1836	6.8	Hayward
June, 1838	7.0+	San Andreas
October 8, 1865	6.3	San Andreas
October 21, 1868	6.8	Hayward
April 19, 1906	8.3[2]	San Andreas
October 17, 1989	7.1[2]	San Andreas

1 Toppozada, et.al.(1981)
2. Measured

The dominant fault in the San Francisco Bay Area is the San Andreas Fault, which extends from the Gulf of California to Point Delgado, and is the boundary between the North American and Pacific crustal plates. Other major active faults in the

region include the Hayward, Calaveras, and the Seal Cove-San Gregorio faults. The Hayward fault trends northwestward along the base of the hills behind the East Bay cities of Fremont northwest to Richmond. The Calaveras fault diverges northward from the San Andreas fault south of Hollister and continues northward through the western slope of the Diablo Range. The Seal Cove - San Gregorio fault system trends northward from the mouth of Monterey Bay, along the coast of San Mateo County and extends toward Dunbury Point in Marin County.

All these faults trend northwesterly and display a similar right-lateral, primarily horizontal movement. The proximity of the site to active faults is presented in Table 3-2. There are other active, but smaller faults throughout the region, but because of their distance from the site or their size, they are not considered capable of causing significant earthquake shaking within the project area.

Table 3-2
Significant Faults - Balboa Reservoir

Fault	Distance to the site (miles)	Fault Length (miles)	Maximum Richter Magnitude (assigned)	Maximum Richter Magnitude (historical)
San Andreas	4	270[1]	8.3	8.3
Hayward	14	60	7.2[2]	6.8[3]
Calaveras	25	73	7.3[2]	6.7
San Gregorio	7	106	7.4[2]	6.1
Concord	27	12	6.4[2]	5.4
Rodgers Creek	30	45	7.1[2]	5.7

1. Northern segment
2. Slemmons (1982)
3. Estimated

There are no known active faults at the site. However, the northwest trending City College Fault passes beneath the northeast corner of the north basin. The City College Fault is defined by an aligned zone of crushed and sheared Franciscan Complex, however there is no evidence of faulting in the overlying Colma formation. The City College Fault is therefore considered inactive.

Geotechnical Evaluations

Available Data. Two geotechnical investigations were previously performed by other consultants at Balboa Reservoir site. The reports, prepared by Earth Sciences Associates (ESA) and Morrison-Knudsen Engineers, Inc. (MKE) which we reviewed are:

> Report
> Geotechnical Investigation of Balboa Reservoir
> For San Francisco Water Department
> San Francisco, California
> By Earth Sciences Associates
> Dated May 1974

> Report
> Seismic and Geotechnical Re-evaluation of the North Basin, Balboa Reservoir
> For Utilities Engineering Bureau
> City and County of San Francisco
> By Morrison-Knudsen Engineers, Inc.
> Dated June 1987

In addition we reviewed the existing plans and specifications developed for construction of Balboa Reservoir and provided to us by the San Francisco Public Utilities Commission. The above data were utilized in developing our conclusions and recommendations for this project.

Subsurface Conditions. Subsurface conditions at the site were explored and evaluated by drilling 14 borings and excavating 7 test pits in the ESA study, and drilling 10 borings and excavating 10 test pits in the MKE study. The locations of the borings and test pits are shown on Plate 4. The borings drilled by ESA extended to depths ranging from 16 to 60 feet. The borings drilled by MKE extended to depths of 15 to 115 feet.

The test pits excavated by ESA and MKE were shallow, extending to depths of less than 5 feet. In addition, a seismic refraction survey program consisting of 5 seismic survey lines was performed in the ESA study at the locations shown on Plate 4 - Boring Location Map.

The results of the previous studies indicate that the native soils at the site generally consist of dense to very dense sands and silty sands of the Colma Formation. The embankment materials generally consist of earth fill, with the exception of the outer portion of the exterior slopes which consists of rockfill covered by a thin layer of topsoil. Construction specifications called for at least 92 percent relative compaction for embankment materials as determined by ASTM 1557 test method. The results of the field exploration by ESA and MKE indicate that the majority of the embankment fills were compacted to at least 92 percent relative compaction as required in construction specifications. The earth fill materials generally consist of dense to very dense sand to silty sand soils excavated originally from Colma Formation. However, a layer of medium dense sand to silty sand soils was encountered in MKE Study in Borings B-4, B-5, B-6, B-7, B-8, and B-9, at depths of 15 to 30 feet. The Standard Penetration Test (SPT) blow counts on these materials ranged form 15 to 24 blows/foot.

Groundwater levels indicated in the ESA report ranged from approximately elevation 260 feet at the southwest corner of the northern basin (corresponding to a depth of about 21 feet below the basin floor) to approximately elevation 280 feet in the northeast corner of the northern basin (corresponding to a depth of about 4 feet below the basin floor).

Groundwater levels measured in the MKE study in May 1987 ranged from approximately elevation 255 to 251 feet (corresponding to depths of about 29 to 20 feet below the basin floor).

The MKE study also indicates that the logs of borings drilled prior to construction show that the soils in five borings along the north and east side of the northern basin were wet below elevation 285 to 290 feet. However, no water level data were presented in the logs of boring.

Seismic Stability Evaluation. The ESA study indicates that a dense zone of foundation soils (with SPT blow counts ranging from 32 to 50) in the southeast corner of the southern embankment has liquefaction potential during the maximum credible earthquake. The ESA study predicts a permanent seismically-induced deformation on the order of 1 to 2 inches in the embankment slopes during the maximum credible earthquake. The ESA study was performed using a simplified dynamic response analysis procedure developed by Ambraseys and Sarma (1967).

The MKE study concludes that a zone of medium dense sand to silty sand materials, encountered in Borings B-4, B-5, B-6, B-7, B-8, and B-9 is liquefiable under a maximum credible earthquake, which would be an 8.3 Richter magnitude earthquake occurring in San Andreas fault approximately 4 miles from the site. The liquefaction potential evaluation in MKE study was performed using a simplified dynamic response analysis procedure and without considering the effects of initial shear stresses on resistance of the soils to liquefaction.

The MKE dynamic response analyses were performed using the computer program SHAKE which evaluates the response of horizontal soil layers to seismic shaking. However, a two-dimensional dynamic response analysis of the embankment could model the seismic response of the embankment more realistically and could estimate accelerations and equivalent dynamic shear stress ratios with higher accuracy.

The results of previous studies (Seed, 1981) indicate that the resistance of a soil to liquefaction or strength loss due to application of cyclic loading is highly dependent on the existing static shear stress in the soil before application of cyclic loading. For a given cyclic stress ratio, the higher the ratio of initial shear stress (the static stress ratio), the larger the number of stress cycles required to cause liquefaction or cyclic strength loss.

The following equation can be used to estimate the cyclic stress ratio τ_{av}/σ_o' required to cause liquefaction in the presence of a static shear stress ratio, $(\tau/\sigma_o') = \alpha$ if the τ_{av}/σ_o' value at $\tau/\sigma_o' = 0$ is known:

$$\left(\frac{\tau_{av}}{\sigma_o'}\right)_{\alpha=\alpha_o} = \left(\frac{\tau_{av}}{\sigma_o'}\right)_{\alpha=0} \cdot R$$

Plate 5 shows average values of cyclic stress ratio factor, R, versus static stress ratio, ,for sands.

Based on the above discussions, it is our opinion that a more realistic seismic stability evaluation of the embankment should include the following steps:

1. Evaluation of the dynamic response of the embankment foundation system by an appropriate two-dimensional dynamic response analysis.

2. Evaluation of pre-earthquake static shear stresses in the embankment and foundation soil by an appropriate two dimensional static stress analysis.

3. Evaluation of the liquefaction potential of various soil elements based on the results of steps 1 and 2 as summarized above.

4. Assessment of the stability of the embankment and foundation during and after earthquake shaking based on the results of steps 1 through 3 as summarized above.

A reevaluation of liquefaction potential and seismic stability of the eastern and western embankment of the northern basin of Balboa Reservoir was made in this study by using the above-discussed procedure. Our liquefaction potential and seismic stability evaluations did not include the northern and southern embankments of the northern basin because adequate geotechnical data do not exist for liquefaction potential and seismic stability evaluation of these embankments. Finite element analyses were performed to evaluate the seismic response of the western embankment and foundation soils in order to estimate accelerations and seismically-induced shear stresses in the embankment and foundation materials. A representative cross section of the western embankment used in our analyses is shown on Plate 6 - Geotechnical Profile. The computer program FLUSH (1975), which has been widely used for seismic analyses of earth dams, was used for the seismic safety reevaluation of the existing embankment. The FLUSH analysis method is a two dimensional finite element analysis method using the frequency domain solution procedure. In view of the relatively high length to height ratio of the existing embankment, it is our opinion that a two dimensional model of the

embankment and the underlying soils would adequately model the embankment and foundation system. The FLUSH analysis is performed using the assumptions and limitations as summarized in the following paragraphs:

- The foundation medium is assumed to be horizontally layered soil strata overlaying a rigid base rock. No wave transmitting boundary is used at the rigid base rock.

- The seismic input motion is assumed to be vertically propagating plane seismic S and P waves. The motion is prescribed at a given elevation within the free-field soil medium. The program can perform free-field deconvolution analysis of the input motion to generate the base rock motion for the interaction analysis.

- The soil material is assumed to be linear viscoelastic material characterized by the complex moduli with constant hysteresis damping. The soil shear modulus and damping ratio can be specified as shear strain-dependent properties. The strain-dependent soil properties can be specified differently for every soil element in the finite element model.

- The program is a linear analysis program. However, it has the capability of automatically or manually performing a series of iterative, equivalent linear analyses to ensure strain compatibility of strain-dependent soil properties.

- The program has the options of specifying the horizontal wave transmitting boundary along either one or both side boundaries of the foundation soil model and the viscous wave transmitting boundary at any point in the plane of the soil model to simulate 3-D wave radiation effect. Both transmitting and viscous boundaries were used in our finite element model.

- The 2-D foundation soil strata and embankment materials are modeled with plane strain finite elements.

The application of the FLUSH program follows three distinct analysis modes, namely, the free-field response analysis mode, the response analysis mode, and the response iteration mode.

The free-field response analysis mode performs the free-field convolution and deconvolution of the input seismic motion and determines the strain-compatible soil properties based on the free-field soil response strains. It also

determines the properties of wave transmitting boundary consistent with the free-field strain-compatible soil properties.

The response analysis mode performs the solution of the frequency domain equations of motion for the embankment-foundation system giving the response transfer functions at the desired locations.

The response iteration mode performs iterative equivalent linear response analyses to ensure soil properties compatible with the embankment foundation response induced soil strains.

Our FLUSH analyses were performed for a generalized soil profile representing site subsurface conditions shown on Plate 6. Nonlinear soil behavior was approximated by using strain-dependent, equivalent linear soil properties presented by Seed and Idriss (1970). The synthetic earthquake acceleration time history developed by Seed and Idriss (1969) normalized to a peak acceleration of 0.60g was used as maximum credible earthquake bedrock acceleration time history in our dynamic response analyses.

Effective seismically-induced shear stress ratios (defined as 65 percent of the maximum seismically-induced shear stress ratios) and the peak accelerations as computed from our dynamic response analyses are presented on Plate 7 - Cyclic Stress Ratios and Plate 8 - Maximum Accelerations.

Pre-earthquake static stress ratios in embankment and foundation soils were estimated using a linear elastic static stress analysis. Plate 9 - Static Stress Ratios, presents the contours of the static stress ratios in the embankment before the earthquake. Since there was no previous study on the stress-strain relationship of the embankment and foundation materials, the results of simplified linear elastic calculations of Poulos et al. (1972) were used for the purposes of this analysis. The studies by Lee and Idriss (1975) show that for many cases a simple linear elastic single step analysis will give satisfactory results for estimating static stresses in embankments.

The relationship between cyclic stress ratios and SPT blow counts presented by Seed and Idriss (1982) and shown on Plate 10 - Liquefaction Data, were used for

liquefaction potential evaluation in this study. The recorded SPT blow counts were corrected for various factors as suggested by Seed and Tokimatsu (1985), and the cyclic stress ratios shown on Plate 10 were increased by 120% to take into account the longer duration effects of an 8.3 Richter Magnitude earthquake.

Our liquefaction potential evaluation was made based on the results of static stress analyses presented on Plate 9, the calculated dynamic stress ratios shown on Plate 7, the liquefaction resistance data presented on Plate 10, and the relationship between static stress ratios and resistance to liquefaction, as shown on Plate 5. Based on the results of our evaluation, it is our opinion that the foundation materials in southeastern portion of the south basin, identified as liquefiable soils in the ESA study, are not liquefiable. However, the results of our evaluation indicate that a portion of the western and eastern embankment of the north basin is liquefiable under the maximum credible earthquake as concluded by MKE study.

Consequences of liquefaction could be settlement and cracking of the embankment and failure of some portions of the embankment slopes. To mitigate the liquefaction potential, either the reservoir should be lined and provided with subdrains or the liquefiable soils should be grouted.

The results of the seismic stability evaluation presented in this section are based upon the limited available subsurface data obtained in the ESA and MKE studies. As shown on Plate 4, more subsurface data are available in the north basin than the south basin. Therefore, additional subsurface exploration and laboratory testing program would be required to further characterize foundation and embankment soil conditions in the south basin.

Structural Considerations

The proposed Balboa Reservoir is made up of two basins: North Basin and South Basin. These basins are similar in size and shape. Each of the basins measures approximately 870 feet long by 540 feet wide by 31 feet deep. The roof structure of the South Basin was designed in 1978, but was not constructed. The purpose of this study is to evaluate the structural design of the South Basin structure based on the original drawings provided by the San Francisco Water Department.

We have completed a conceptual evaluation of the structural design of the roof structure and found it to be satisfactory. However, the construction details have not been checked. The design drawings show a structural system that consists of two expansion joints in the north-south direction and one expansion joint in the east-west direction, thus dividing the structure into six sections. The general layout is shown on Plate 11.

The roof construction is made up of an asphalt wearing surface (with a waterproofing membrane) on top of precast-prestressed double T's that are supported by precast-prestressed girders. The girders are in turn supported by precast columns. Spread footings support the columns and walls, and the bottom of the reservoir is lined with concrete. Plate 12 shows general cross-sections of the structure.

As shown on Plates 11 and 12, there is a concrete wall at the perimeter of the basin. Also, concrete shear walls are introduced in each direction (east-west and north-south) in each section. These shear walls in each section, together with the perimeter wall, will function as the lateral force resisting elements for each section.

The North Basin and South Basin have approximately the same dimensions. The operating conditions of the basins are also very much the same. Because of these factors, the design of the roof, columns, and walls for the North Basin should be the same as the design of the South Basin.

FRANCISCO RESERVOIR

Site Conditions

The Francisco Reservoir site consists of an existing reservoir impounded by a berm constructed on a bench cut into the north slope of Russian Hill. The elevation at the top of the cut south of the bench is 138 feet, and the elevation

of the bench itself is 125 feet. The average slope from top of cut to bench is 2.5:1 (H:V), although the slope is not uniform and locally may be steeper than 1.5:1. The outboard berm was constructed to elevation 140, and contract drawings show that the downstream toe catches the original ground at about elevation 120.

The cut slope south of the reservoir has a thick cover of blackberry vines and ivy and a scattering of native and exotic shrubs. No rock outcrops were observed in the cut area during our site visit. The slope below the downstream toe of the berm is also covered with vegetation and no rock outcrops were observed in that area.

Geologic Conditions

Francisco reservoir is located in the northeast corner of San Francisco on the north slope of Russian Hill. The hill is underlain by shale and sandstone of the Franciscan Complex (Schlocker, 1974), a highly deformed marine suite of great age and complexity. Contract drawings suggest that at the reservoir site, the Franciscan may have been mantled with 5 to 10 feet of slope debris, but that the elevation 125 bench was cut into "bedrock" except along and near the upstream toe of the outboard, or north berm. Schlocker's map indicates that much of the bedrock should be shale with some sandstone encountered at the southeast corner of the reservoir.

Seismicity and Faulting

The seismic setting for Francisco Reservoir is similar to that of Balboa Reservoir presented previously.

The proximity of Francisco Reservoir to active faults is presented in Table 3-3: Significant Faults - Francisco Reservoir.

Table 3-3
Significant Faults - Francisco Reservoir

Fault	Distance to the site (miles)	Fault Length (miles)	Maximum Richter Magnitude (assigned)	Maximum Richter Magnitude (historical)
San Andreas	8	270[1]	8.3	8.3
Hayward	11	60	7.2[2]	6.8[3]
Calaveras	24	73	7.3[2]	6.7
San Gregorio	10	106	7.4[2]	6.1
Concord	24	12	6.4[2]	5.4
Rodgers Creek	24	45	7.1[2]	5.7

1. Northern Segment
2. Slemmons (1982)
3. Estimated

There are no known active faults at the site.

Geotechnical Evaluation

Available geologic data indicate that the site is underlain by sandstone and shale of the Franciscan Formation at shallow depths. No site specific subsurface data exist for the site; however, we reviewed 5 geotechnical investigation reports prepared by others for the existing apartment and condominium buildings in the vicinity of the site. The results of the above investigations indicate that the bedrock consisting of sandstone and shale of the Franciscan Formation was encountered at depths ranging from 0 to 13 feet in the vicinity of the site. The upper 10 to 20 feet of the bedrock materials consist mostly of weathered and fractured materials. Below 10 or 20 feet, the bedrock becomes moderately hard to hard. Contract drawings indicate that 10 to 30 feet of material was removed to construct the level bench on which the reservoir is sited, therefore it appears that the reservoir is founded on Franciscan Formation shale and sandstone, or that the rock is at relatively shallow depths below the reservoir.

Depth to groundwater at the site is not known; however, we saw no springs or seeps at the base of the cut south of the reservoir, which is about 30 feet below original ground.

The available data are not adequate for evaluating static and seismic stability of the embankment and foundation materials. The bedrock units, as encountered in the previous studies performed in the vicinity of the site, would provide adequate foundation support for the proposed improvements. However, a site-specific geotechnical study should be performed to explore and evaluate subsurface conditions and provide geotechnical recommendations for design and construction of the proposed improvements. The geotechnical investigation should also include seismic stability evaluation of the existing slopes at the site using the site specific data obtained in the study.

Structural Considerations

Existing Construction. The Francisco Reservoir, with a capacity of approximately 2.5 million gallons, measures 410 feet long by 120 feet wide by 8 feet deep. The reservoir site is made up of cut and fill (see geotechnical sections). The existing structure consists of rows of redwood posts and beams with a wood deck plus 3-ply felt and gravel roofing (the posts rest on concrete pads). At some point in the reservoir's history, rows of new redwood posts were placed between the existing posts in order to strengthen the roof. The bottom of the reservoir is lined with brick and in some areas partially covered with concrete as a result of repairs and modifications made over the past years. There are earth berms on three sides of the reservoir with the fourth (east) side consisting of a series of reinforced concrete retaining walls.

Present Condition. The brick lining in some areas is deteriorating. The new redwood posts are generally in good condition. However, many of the older redwood posts are showing some signs of deterioration near the bottom of the posts and at the water line level. The girders are in good condition. The roofing of the reservoir is aging and shows great signs of wear. Boards are cracked and loose, and in many areas daylight can be seen through the cracks. Plate 13 shows a portion of the problem area.

Recommendation. The Francisco Reservoir is not in use at the present time. If this reservoir is to be put back into the City's distribution system, it must be repaired. If this site can be reused from the geotechnical point of view, the following remedial measures should be performed. First, the deteriorating lining

at the bottom of the reservoir should be removed and replaced with a concrete slab. Second, new redwood posts should be installed to replace the decaying posts. Third, the existing roof should be removed and a new roof constructed similar to the existing one. After the above remedial steps have been taken, the Francisco Reservoir can be returned to service.

However, a hydraulic study indicates that the Francisco Reservoir water level must be raised to between Elevation 145 and 150 if it is to be integrated with the present San Francisco water distribution system. This will require the height of the berms be raised ten to fifteen feet and the brick lining replaced. The entire deck, roofing, columns, and foundation must be replaced with a structural system similar to that of the Balboa Reservoir South Basin.

If the structural system for Balboa Reservoir is followed, the roof structure will consist of an asphaltic wearing surface on top of prestressed T's that are supported by precast-prestressed girders and columns. Footings for columns will be integral with bottom lining. As in the case of Balboa Reservoir, intermediate concrete shear walls will be used together with the perimeter wall to form a lateral force resisting system.

COST ESTIMATES

Since the south basin of Balboa Reservoir was designed and reviewed, it is used as a basis for cost estimate. The total cost to construct the Balboa South Basin roof is estimated to be approximately $24.0 million dollars (1990 dollars). This cost excludes utility work, drainage, and other site improvements such as grouting. The cost of grouting would be approximately $10 per cubic yard of the soil to be grouted.

The estimated cost to upgrade the Francisco Reservoir will be about $4.3 million dollars. The cost, also in 1990 dollars, includes the following items:

- Demolition and disposition of the existing structure.
- Construction of a new roof structure and a new lining at the bottom.
- Construction of a new berm on the south side and a modified berm on the north and west side.
- New retaining walls at the south and east sides of the reservoir.

The estimate does not include any utility work, drainage, or other site improvement costs. Additional costs may accrue once the final design configuration has been determined, and due to the limited size of the site and its hillside location. A breakdown of the cost estimate is presented in Table 3-4.

Table 3-4

Cost Estimate
For Francisco Reservoir

No.	Structure	Price per Unit	Quantity	Price per Reservoir
1.	2" Asphalt Pavement	4.65/S.F.	49,200 S.F.	$228,780
2.	Membrane	1.22/S.F.	49,200 S.F.	60,024
3.	4" Concrete Topping	4.35/S.F.	49,200 S.F.	214,020
4.	Precast T-Beam	5.03/S.F.	49,200 S.F.	247,476
5.	Precast Beam	4.35/S.F.	49,200 S.F.	214,020
6.	Column	2.81/S.F.	49,200 S.F.	138,252
7.	Grade BM Lining Footing	14.26/S.F.	49,200 S.F.	701,592
8.	Misc. Concrete 6"	7.54/S.F.	49,200 S.F.	370,968
9.	Excavation	1.1/S.F.	49,200 S.F.	54,120
10.	Backfill	0.066/S.F.	49,200 S.F.	3,247
			SUBTOTAL	2,232,499
11.	Stripping	15/C.Y.	6,666.6	100,000
12.	Berm	50/C.Y.	13,333.33	666,667
13	Retaining Wall -Base -Wall	700/C.Y.	518.5	362,950
14.	Demolition	4.0/S.F.	900.00	360,000
			SUBTOTAL	3,722,116
			CONTINGENCIES 15%	558,317
			TOTAL	4,280,433

Table 3-5

Cost Estimate
For Balboa Reservoir South Basin

No.	Structure	Price per Unit	Quantity	Price per Reservoir
1.	2" Asphalt Pavement	4.65/S.F.	461,578 S.F.	$2,146,338
2.	Membrane	1.22/S.F.	461,578 S.F.	563,125
3.	4"Concrete Topping	4.35/S.F.	461,578 S.F.	2,007,864
4.	Precast T-Beam	5.03/S.F.	461,578 S.F.	2,321,737
5.	Precast Beam	4.35/S.F.	461,578 S.F.	2,007,864
6.	Column (2 X x X 3)	2.81/S.F.	461,578 S.F.	1,297,034
7.	Grade BM Lining Footing	14.26/S.F.	461,578 S.F.	6,582,102
8.	Misc. Concr. 6"	7.54/S.F.	461,578 S.F.	3,480,298
9.	Excavation	1.1/S.F.	461,578 S.F.	507,736
10.	Backfill	0.066/S.F.	461,578 S.F.	30,464
			SUBTOTAL	20,944,562
			CONTINGENCIES 15%	3,141,684
			TOTAL	24,086,246

9838text.3/303(m)

CHAPTER 4

RESERVOIR BENEFITS

POTENTIAL BALBOA SERVICE AREA

A preliminary examination of topography and existing piping was made to determine the feasibility of creating a new pressure zone serviced by Balboa Reservoir. Balboa has an overflow elevation of 312 feet and is about 30 feet deep. Under static conditions, the reservoir could serve areas between about the 100-foot and 220-foot contours with pressures from 40 to 90 psi. Figure 4-1 shows these contours relative to existing pressure zones.

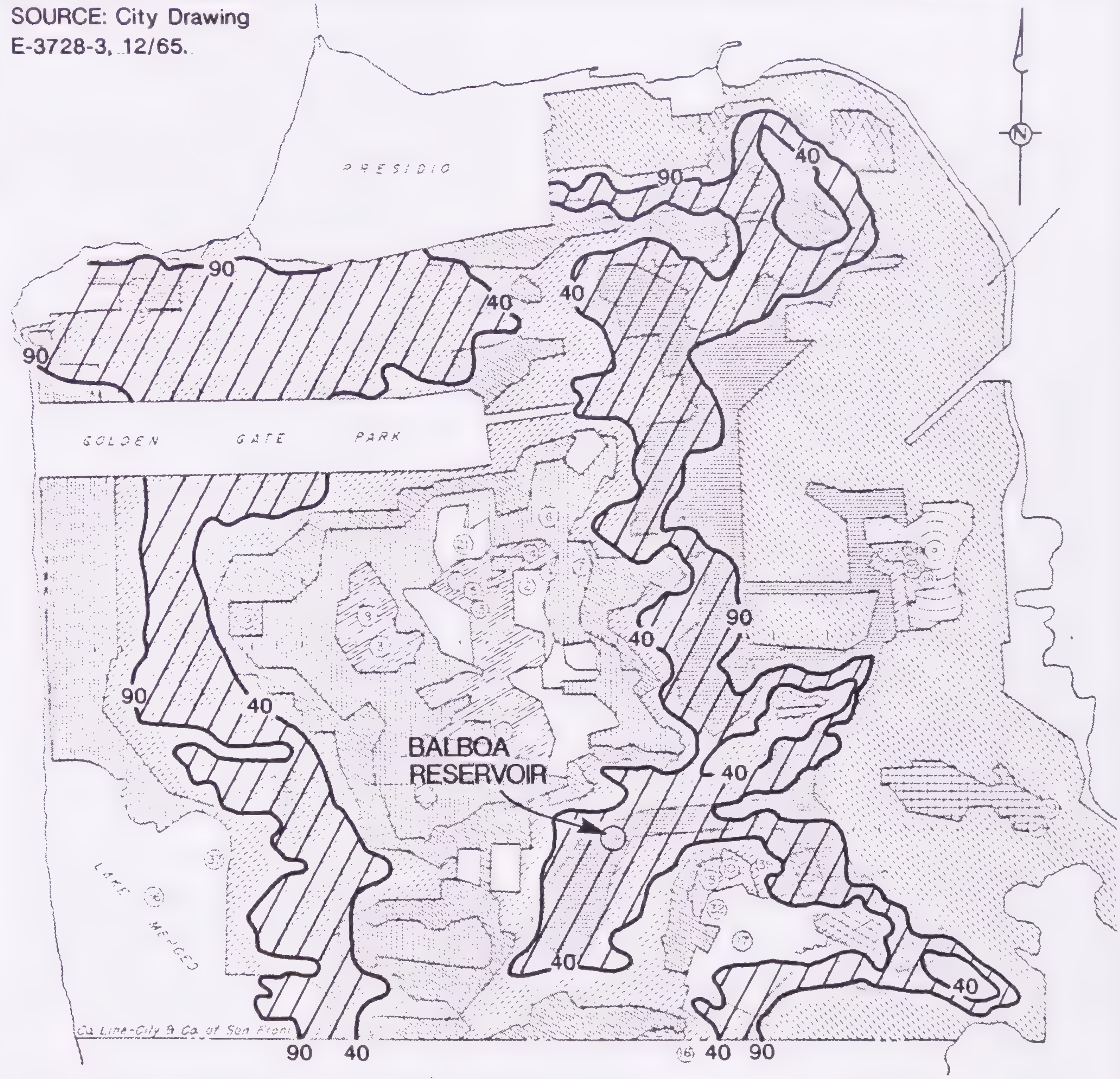
Within the College Hill pressure zone, Balboa Reservoir could serve the portions in the Western Addition and the portions south of the freeway. Figure 4-1 suggests that areas adjacent to Nob Hill, presently supplied by Sunset Reservoir, could also be served. However, lower residual pressures resulting from head losses under flow conditions would shift the area served to lower elevations adjacent to Columbus and Market Streets. Another constraint in the Nob Hill area is the supply to Lombard Reservoir. This reservoir, with an overflow elevation of 303 feet, must continue to be served from Sunset Reservoir.

Balboa Reservoir could also serve a narrow band east of Twin Peaks. This band overlaps portions of both the College Hill and Sunset pressure zones. Dedicating the entire band to a Balboa pressure zone would cause low pressures at the higher elevations. However, this area is served by a pair of north-south pipelines in the Sunset pressure zone, one of which could be dedicated to Balboa service. Such an arrangement could create problems as well; looping of the Sunset system would be reduced, and deliveries to the Sunset-served Potrero Hill Reservoir would be limited. Alternatively, the displaced fringe areas in the Sunset zone could be served from the 500-foot elevation Sutro Reservoir.

With pressure reduction, lower areas east of Twin Peaks in the College Hill and University Mound pressure zones could be served by Balboa Reservoir.

FIGURE 4-1

SOURCE: City Drawing
E-3728-3, 12/65.



LEGEND

- SUNSET RESERVOIR.
- UNIVERSITY MOUND AND FRANCISCO STREET RESERVOIRS.
- STANFORD HEIGHTS RESERVOIR.
- COLLEGE HILL RESERVOIR.
- MERCED MANOR RESERVOIR.
- SUMMIT RESERVOIR.
- SUTRO RESERVOIR.
- LOMBARD STREET RESERVOIR.
- POTRERO HEIGHTS RESERVOIR.
- McLAREN PARK TANK
- MT. DAVIDSON TANK.
- LA GRANDE TANK.
- KEITH STREET TANK.
- POTRERO HEIGHTS TANK.
- LINCOLN PARK PUMP & TANK.
- PALO ALTO AVE. PUMP STATION.
- CROCKER AMAZON PUMP STATION.
- BERNAL HEIGHTS PUMP
- HUNTERS POINT RESERVOIR

Potential Balboa Reservoir Service Area (Contours of 40 PSI and 90 PSI static pressure)

City of San Francisco
Water Department/UEB
BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Potential Balboa Reservoir Service Area

LEEDSHILL-HERKENHOFF, INC.

West of Twin Peaks, Balboa could serve the lower elevations of the Sunset pressure zone, as well as virtually the entire Richmond District. The Richmond District currently experiences high pressures, and thus could benefit from service from the lower Balboa Reservoir. If the Richmond District were made part of a Balboa pressure zone, fringe areas of Russian Hill, Nob Hill, and Chinatown would be isolated from the Sunset supply, for which Sutro and Lombard Reservoirs would have to make up the difference. However, the Richmond and Sunset Districts are remote from Balboa Reservoir, and were eliminated from consideration based on excessive feeder main costs.

POTENTIAL FRANCISCO SERVICE AREA

Francisco Reservoir, with an overflow elevation of 135 feet, can serve areas no higher than about elevation 40 feet at pressures of 40 psi or more. Such an area would include most of the Marina and North Beach Districts. It could also include most of the Financial District, to as high as Kearney Street. Raising the reservoir by up to an additional 40-feet to elevation 175 feet would only marginally expand the service area under demand conditions, but would improve the pressure supplied.

Pressure ranges described above are based on static-state conditions -- lower pressures would result from head losses under flow conditions. A hydro-pneumatic tank on the site was not considered, since the area can be more efficiently fed by gravity from Lombard, Sunset, or University Mound Reservoirs.

DEVELOPMENT OF HYDRAULIC MODELS

To evaluate the benefits of incorporating Balboa and Francisco Reservoirs into the water supply system, LH has developed models of portions of the City's distribution system. These models were used to evaluate whether existing or proposed pipelines and reservoirs can provide projected maximum day, peak hour, and fire-fighting flows. A pipe network analysis program capable of calculating the pressures and flows through the distribution mains and the storage in the

reservoirs has been utilized. The computer program used in the steady state modeling is the University of Kentucky pipe network analysis program "KYPIPES", a state-of-the-art program which is widely used in the industry.

Existing Computer Models

Pitometer Associates did some modeling of the City system about 15 years ago. CDM performed KYPIPES modeling of Peninsula system in 1988/89 as part of their study of the Crystal Springs Water Treatment Plant alternative. The City does not have copies of these models, only the resulting final reports. These reports were reviewed by LH as part of the present study.

SFWD City Distribution Division initiated KYPIPES modeling of the City system. Completed models of the Sunset and University Mound pressure zones were furnished to LH. These models include data on pipe length, age, and elevation, as well as water demand data. These models were modified for use in this study.

KYPIPES Model

The KYPIPES model solves a series of flow equations for a given steady state condition. It creates "loop equations" which express mass continuity and energy conservation for flow through each pipe in the distribution network.

The technique used to solve this system of equations uses an arbitrary initial value for the flow in each line. The system of linearized equations are solved using routine matrix procedures. The resulting set of flow rates is used for the new initial values, and the calculation repeated. This procedure is repeated until the change in flow rates obtained in successive trials is insignificant.

KYPIPES also has the ability to model dynamic conditions for the distribution network. Dynamic modeling called "Extended Period Simulation" (EPS) is used to show the changes in the condition of a pressure zone over time. This allows variables such as the water surface elevation of a reservoir to be monitored throughout a specified demand period. The EPS runs are calculated by combining

a series of steady-state model runs over the time period. Though the scope of this project calls for only a steady-state analysis of the distribution network, some EPS runs were made to verify dynamic reservoir performance.

KYPIPES model output includes pressure, hydraulic grade line, and demand for each node as well as the flow rate and head loss along each section of pipe. The model computes the continuity equations first, determining flow rates, velocities, head losses, and the hydraulic grade lines. As the final step, pressures are calculated by taking the difference between the street elevation and hydraulic grade line and converting to pressure, expressed in pounds per square inch (psi).

The existing City models included pipe roughness coefficients and the distribution of demand throughout the service areas. Pipe roughness is modeled using a Hazen-Williams "C-factor". Head loss through a pipe is proportional to its C-factor. New water main typically has a C-factor of about 130. The C-factor of older pipe may decline to a value of 50 or less before being taken out of service. A curve showing the relationship of C-factor to pipe age was provided by the City. This curve was developed from standard references and modified by actual measurements of SFWD piping made by Pitometer Associates over a 30-year period. Pipe diameter, material, and installation date are tabulated in the City's "gate book"[1]. The City presently has an on-going program for mortar-lining mains of 20 inches in diameter and larger. To reflect this, LH engineers adjusted the C-factor of these pipes to a value of 110, to reflect a mortar-lined pipe with valves, tees, and elbows in service for about ten years.

Water demands used in the City models were adjusted to reflect the ultimate (year 2035) City demands by taking the ratio of the ultimate City demand to theexisting demand given in the model input, and scaling the original demand data by this factor at each individual node throughout the pressure zone.

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[1] "Gate books" are detailed maps of the distribution system. These maps include all distribution mains, including those of small diameter. Surface elevations are given for each intersection. Other City gate books contain data on pipe installation dates.

Water Transmission System Schematics

Schematic drawings were prepared for use in developing, understanding, and updating the computer models. These schematics provide valuable assistance in interpreting results, and provide a convenient means for permanent documentation and updating. Reduced copies of the water transmission schematics are presented as Plates in the Appendix of this report.

Pipe segments and junctions as well as schematic details of reservoirs, booster pumps, etc. are shown on the schematic drawings. Only those pipe segments which have hydraulic significance to the performance of the system have been included in order to simplify the model. For pressure calculations, the model uses the surface elevation at the nearest street corner. These elevations are taken from the City's 1987 gate book. Pressures calculated by the model thus reflect delivery pressure at street level.

ADEQUACY OF EXISTING SYSTEM

The models formulated for the Sunset, College Hill and University Mound pressure zones were first evaluated to determine the adequacy of the existing system under ultimate demand flows.

Sunset System Model (385-foot service)

The SFWD Central Distribution Division (CDD) provided LH with a KYPIPES model for the Sunset Reservoir pressure zone. The total present day system demand in this model is 28.25 million gallons per day (mgd). With this model the City included peak flow and fire flow runs. The fire flow run was made with average day demands and a 11.52 mgd (8000 gpm) fire near Haight and Divisidero Streets.

Map F-464 "Sunset Feeder Mains" and a piping schematic of the Sunset system were provided by the City. Pipes of 12-inch and larger are included in the schematic. The Sunset pressure zone has two sources of supply: the 54-inch San Andreas pipeline running along Junipero Serra Street, and the 60-inch Sunset supply line

extending from the Lake Merced pump station to Sunset Reservoir. In normal operation, Sunset Reservoir is filled primarily from the Lake Merced pump station. When filling from the San Andreas pipeline, the flow is throttled back to Sunset pressure at the San Pedro valve lot, and directly serves the southern portion of the Sunset service area. Both Sunset Reservoir and the San Andreas pipeline were set at the Sunset overflow pressure of 385 feet in the City model.

The piping network schematic for the Sunset pressure zone is presented in Plates 2-NW, 2-NE, 2-SW and 2-SE. Several changes were made to the demand distribution to more accurately model the Sunset system:

- Existing demands were scaled up to the 35.36 mgd ultimate average day demand. Sunset pressure zone accounts for an estimated 32 percent of the 110.5 ultimate average day demand.

- A 13.3 mgd demand was placed at the Roanoke PRV vault (node 189 on the piping schematic). This demand represents the flow of water through the PRV supplying the College Hill pressure zone.

- A 3.32 mgd demand was added at Hyde and Lombard Streets (node 142) to account for the demand at Lombard Reservoir.

- A 1.11 mgd demand exists at node 175 in the Potrero Hills District representing the demand of Potrero Hill reservoir.

Roanoke Valve Vault calibration. Using actual gage readings taken from the Roanoke valve vault it was possible to verify results given from the Sunset model. Model results show that the water entering the City through the 54-inch San Andreas pipeline feeds the southern parts of the Sunset service area and is transferred to the 44-inch Crosstown pipeline. The model shows no flow from the San Andreas Pipeline to Sunset Reservoir under steady-state conditions.

To determine the correctness of this result, actual readings from the PRV pressure recorder were analyzed. Friction losses taken from the model were scaled down from ultimate City demand values to present day levels. This

analysis indicates that at present flow rates, there is approximately 30 feet of head loss between the Roanoke Vault and the intersection of the Crosstown Pipeline and 54-inch San Andreas line. By adding this loss to the hydraulic grade line recorded at the vault it was determined that the hydraulic grade line at the intersection was approximately 368 feet, and thus below the minimum 385 feet needed to provide water to Sunset Reservoir.

Actual measurements suggest that during low demand periods (i.e. night-time demands) it is possible that San Andreas Pipeline flow can reach Sunset Reservoir. The recorded measurements indicate a peak hydraulic gradeline elevation of 391 feet at the Crosstown/San Andreas junction during low demand conditions. This is consistent with CDM's observation that during some demand conditions an estimated ten percent of the flow through the San Andreas Pipeline continues north to Sunset Reservoir.

Since the downstream pressures at the San Pedro Valve Lot were not known, it was not possible to directly confirm the hydraulic grade line at the County line used in the model. The existing model used a fixed-grade node at the County line at the same elevation as Sunset Reservoir (385 feet). It is known, however, that under some flow conditions the City adjusts (throttles) the pressure at the San Pedro valve lot to balance the pressure from Sunset Reservoir. The assumed head at the County line thus appears reasonable.

<u>**Maximum day demand model**</u>. Maximum day demands were modeled by multiplying individual average day demand for each node by 150 percent. The results of the maximum day model run are plotted on Plates 2-NW, 2-NE, 2-SW and 2-SE. At maximum day demand, high pressures exist just north of the reservoir and in isolated areas throughout the system. The highest pressures are at elevations below 110 feet. Maximum modeled pressure is 152 psi located at 23rd and Rhode Island, near the Potrero Reservoir, but high pressures are generally less than 120 psi.

A large area of low pressure exists in the northeast portion of the pressure zone around Pacific Heights and Nob Hill, approximately bordered by Fillmore and Stockton Streets on the west and east, and O'Farrell and Green Streets on the south and north. A small number of these low pressures are not within the Sunset

pressure zone, but are instead served by Sutro reservoir which can feed areas with elevations from about 290 to 407 feet. This includes about 20 blocks around Lafayette Park, and a section northeast of Hyde and California Streets. Pressures in this area range from about 10 to 30 psi under maximum day demand, with an extreme low of 0 psi at the Lombard Reservoir node. Thus Lombard Reservoir would not be refilled under maximum day demand conditions. Elevations in the low pressure areas are usually above 300 feet.

To the east of Twin Peaks, two steeply sloped areas have both high and low pressures occurring within a few blocks. Along Castro Street (node 162) there is one area with a low pressure point. In the Potrero Heights area there are high pressures along 23rd street, with a low pressure point at an elevation of 300 feet.

<u>Peak hour demand model</u>. The peak hour model run shows much the same results as the maximum day model. Some high pressures were brought down to acceptable levels north of Golden Gate Park, but low pressures in the northeast area of the zone decreased even more.

<u>Fire flow model</u>. The first fire flow run consisted of two fires added to the maximum day model. An 6000 GPM fire was modeled near the intersection of Haight and Sanchez Streets. A second fire was added in the south-eastern part of the zone with a demand of 9000 GPM split between nodes. No significant pressure drops were noted as a result of these fires.

In a second fire run, a fire was placed north of Golden Gate Park, with a 9000 gpm fire in the south-eastern part of the zone. The piping network also handles these flows easily in this predominately high pressure area.

A third fire flow model was analyzed with one fire in the low pressure area in the north-east portion of the zone. A 6,000 gpm fire was placed in the neighborhood of Sutter and Hyde Streets, split between nodes 130, 136, 138 and 147. Due to this fire demand, all pressures drop to zero at street level east of Fillmore Street, and head losses in piping leading to the area are significant.

Remedial piping. Presently the Sunset pressure zone experiences both high and low pressure problems. The high pressures exist mainly in the Sunset and Richmond districts with some small high pressure areas scattered throughout the pressure zone. Because the Sunset and Richmond Districts are distant from Balboa Reservoir, using Balboa to solve problems in these areas would not be practicable and was eliminated from consideration based on discussions with City staff.

During peak hour water demand conditions, the hydraulic model indicates that nearly the entire north-eastern area has low pressure problems. Part of the reason for the low pressures in this northeast section is the large hydraulic head loss in the four supply mains extending from the western part of the service area[2]. A head loss of 40 feet is typical for these pipes. To alleviate this, pipe 120 at Post Street was up-sized in the model to a 24-inch pipe in order to improve flow efficiency from the western half of system to the eastern half. Next the 12- and 16-inch east-west pipes were up-sized to 24-inch pipes. This brought most pressures up to at least 20 psi under fire fighting conditions. Costs of this remedial piping total $3.1 million, as shown in Table 4-1.

A second solution considered to solve these low pressure problems involves cross-connection with other pressure zones. Since the problem is associated with the high elevations at the end of the system, connection to Sutro pressure zone (500-foot service) is an alternative. This sort of arrangement is presently done manually by opening divide valves from the Sutro zone to mitigate low pressures caused by fire-fighting flow demands. The PRVs would automate this process, opening automatically whenever pressures drop below the desired pressure set points. Although this would raise all of the pressures to adequate levels, it would result in lower pressures within the Sutro system during maximum day demands. In addition, an energy expense would be incurred to pump additional water to the Sutro zone.

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[2] Pipes 119, 120, 131, and 132 along California, Geary, Oak, and Haight Streets, respectively.

Table 4-1

Cost Tabulation For Remedial Piping
Sunset Pressure Zone

Item	Diameter	Location	Qty	Unit	Unit	Total
CI Pipe	24	Post & Geary (120)	4,800	LF	$106	$508,800
CI Pipe	24	California (119)	5,100	LF	106	540,600
CI Pipe	24	Haight (132)	4,500	LF	106	447,000
CI Pipe	24	Green (185)	4,500	LF	106	447,000
CI Pipe	24	Pacific (184)	2,900	LF	106	307,400
CI Pipe	24	Pacific (188)	1,400	LF	106	148,400
CI Pipe	24	California (178)	2,900	LF	106	307,400
CI Pipe	24	Bush (176)	2,400	LF	106	254,400
CI Pipe	24	Bush (195)	500	LF	106	53,000
			Total			$3,074,000

Using Balboa in this case would not be an alternative solution. The model assumes a 385-foot hydraulic grade line in the San Andreas Pipeline at the County line to reflect supply at Sunset pressures. The hydraulic grade line near Balboa Reservoir under maximum day demand is 365 feet. Since a Balboa pressure zone would have a grade line of only 312 feet, extension of a Balboa pressure zone into this area will not solve the low pressure problems.

College Hill Models (255-foot service)

The College Hill pressure zone has not been previously modeled. A College Hill model was developed by LH engineers for this study. Input for the KYPIPES model was taken from City Drawing F-465, "Merced Manor, Summit, Lombard, College Hill and Hunter's Point Feeder Mains", provided by the San Francisco Water Department. Drawing F-465 is a piping schematic showing the main trunk lines of the College Hill pressure zone and distribution piping down to 12-inches in diameter. To better model the hydraulic characteristics of the system, some 8-inch and 6-inch

pipes were added to the model to provide a looped system. Information on these smaller pipes was obtained from the City's gate books. Node elevations were also taken from the gate books.

College Hill Reservoir is supplied from the Roanoke PRV station. The PRV, at elevation 177, was modeled with a hydraulic gradeline elevation of 295, based on an observed outflow pressure of 50 psi. The reservoir was set at hydraulic gradeline elevation of 255 feet.

The College Hill pressure zone was subdivided into three sub-zones to simplify interpretation of model output and to allow easier location of pipes and nodes. Zone 1100 is located south of the reservoir and much of it is fed directly from the Roanoke PRV station. Zone 1200 includes areas north <u>to</u> Market Street, and Zone 1300 covers areas north <u>of</u> Market street. The piping network schematic for the College Hill pressure zone is presented as Plate 3. Pressure zone boundaries are shown on the map to illustrate areas served by College Hill.

<u>**Average day demand model**</u>. The model was first run for average day demand under the ultimate (year 2035) City-wide demand of 110.5 mgd. College Hill's total demand is about 12 percent of the total City demand, or 13.3 mgd. This demand was then distributed to each node on an area-weighted basis.

The results of the average day run showed no major problems in the College Hill pressure zone. High pressure areas are mainly located in the lower elevations north of San Francisco General Hospital and in a six block area just south of Market. Pressures in these areas range from about 95 to 102 psi.

<u>**Maximum day and peak hour models**</u>. Average day demands were scaled up by 150 percent to model maximum day and 225 percent to model peak hour demands. The pressures, flows, and hydraulic grade lines for maximum day were then plotted on the College Hill pressure zone piping schematic to determine problem areas in the system. The results of the maximum day model are shown on Plate 3[3].

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[3] Areas with indicated low pressures located adjacent to the reservoir and those within zone 1300 are within the Sunset pressure zone. High pressure at Node 1324, south of Market Street, is in the University Mound pressure zone.

The maximum day model shows very similar results to the average day run, with low pressures located at the same nodes. The extreme southern end of the system shows low pressures, due partly to the 6-inch diameter, high-headloss pipe that leads to node 1115. Areas to the extreme northwest of the zone (Western Addition beyond Ellis and Buchanan Streets) have similar low pressure problems due to piping decreased in size to 6 inches and elevations generally above 110 feet.

The two isolated areas of high pressures are still evident in the model run under peak hour flow conditions: the six block area south of Market, and the ten block area just north of San Francisco General Hospital. Since these areas are isolated, it may be possible to control these areas with a PRV without effecting pressures in any other area.

<u>Fire flow model</u>. Two separate fire flow models were made for the College Hill pressure zone. The first run used one fire of 12,000 gpm in the northeastern part of the zone (Geary and Taylor near Downtown in the Theater District) and a second fire of 6000 gpm in the Western addition (Ellis and Buchanan Streets). The effects of these two fires was significant. All pressures of nodes north of pipe 1362, (north of Taylor Street) showed zero pressure at street level, down from maximum day pressures of 60 psi or more. Pipes in this area are old with low C-factors. Pipes leading to this section are all 12 to 16 inches in diameter with only one 12-inch pipe supplying water to the 12,000 gpm fire (pipe 1362). Head losses range from 76 feet per 1000 feet of pipe at Market Street (pipe number 1348) to 1558 per 1000 in at Taylor Street (pipe 1362). Losses are very high along Taylor Street since pipe 1362 is the only pipe supplying water to the fire and velocities would theoretically reach 35 feet per second to meet a fire demand of this magnitude.

The western half of the system, (Ellis at Buchanan Street fire) fared somewhat better, due to a lower fire demand and a more extensive piping network, but pressures are still inadequate to meet fire-fighting flow rates here (node 1338) and throughout the 6-inch piping beyond the fire. Head losses in the pipe leading to the fire are on the order of 10 to 20 feet per 1000 feet of pipe.

A second model placed a demand of 6000 gpm in the high pressure area north of San Francisco General Hospital with a secondary fire of 2500 gpm in the extreme southern end of the system at nodes 1114 and 1115. Similar to the maximum day run, head losses in pipes 1122, 1111 and 1121 are greater than 10 feet per 1000 and pressures drop below 20 psi at node 1114 and to zero at node 1115. The fire demand in the higher pressure area north of the hospital was met easily and pressures remained above the needed 20 psi. By moving the secondary fire closer to the reservoir, near Holyoke and Burrows Streets, the southern end performs better. All pressures in the 1100 zone remain above 20 psi under the 2500 gpm fire fighting demand.

Remedial piping. For the Downtown/Theater District fire (Taylor and Geary Streets), piping changes are needed to alleviate the low pressures and high head losses occurring during a fire. By upgrading pipes 1348, 1347, 1360, 1361, and 1362 from 12 to 16-inch, head losses can be reduced significantly, but pressures are still zero at street levels in the area of the fire. In order to supply 12,000 gpm of water to that area, a 24-inch diameter pipe would be required if flows are to be kept to a velocity of 8 feet/second (through pipe 1362). Alternatively, fire fighting demands can be met by continuing the practice of opening divide valves from the Sunset pressure zone during fire conditions, and reliance on the High Pressure Supplementary System fire supply.

Pressures near the fire at Ellis and Buchanan Streets (Western Addition near St. Francis Square) also dropped to zero at street level under fire demand. All pressures beyond this point dropped to zero as well. In order to bring residual pressures under fire fighting demand up to about 20 psi, pipes in Laguna and Ellis Streets (pipes 1340 and 1349) should be connected with a 20-inch pipe, and pipes in Buchanan and Ellis Streets should be connected (pipe 1349 and pipe 1350 at node 1338). These connections help loop the system more efficiently and bring down the head losses along Buchanan Street (pipe 1350) significantly. To raise the pressures in these nodes to above 20 psi, the pipe in Lower Buchanan Street (pipe 1339) would have to be upgraded to a 16-inch pipe with a C-factor of 110. Cost for this remedial piping, presented in Table 4-2, totals $1.3 million.

The above changes do little to benefit the area beyond Ellis and Buchanan Streets (nodes 1328 and 1338), and pressures in that area remain zero at street level. Elevations in this neighborhood are around 130 to 140 feet. This area could benefit from a new Balboa pressure zone, but pipe changes and upgrades previously discussed would still be necessary.

Table 4-2
Tabulation of Remedial Piping
College Hill Pressure Zone

Item	Diameter	Location	Qty	Unit	Unit	Total
CI Pipe	16	Buchanan(1339)	2,000	LF	$ 97	$ 194,000
CI Pipe	24	Laguna (1340)	560	LF	106	59,300
CI Pipe	16	Market (1348)	2,100	LF	97	203,700
CI Pipe	16	Taylor (1347)	375	LF	97	36,375
CI Pipe	16	Taylor (1360)	450	LF	97	43,650
CI Pipe	16	Taylor (1361)	225	LF	97	21,825
CI Pipe	16	Taylor (1362)	675	LF	97	65,475
CI Pipe	16	Taylor (1363)	300	LF	97	29,100
CI Pipe	12	Geneva (1111)	1,500	LF	72	108,000
CI Pipe	12	Alemany (1121)	5,000	LF	72	360,000
CI Pipe	12	Tingley (1114)	2,400	LF	72	172,800
					Total	$ 1,294,285

<u>University Mound Pressure Zone (172-foot service)</u>

University Mound Reservoir, located in the southeastern part of the City, is comprised of two basins with 140.1 MG of total storage and an overflow elevation of 172 feet. University Mound serves eastern portions of the City including China Basin and Downtown, and northern portions including North Beach and the Marina District. The service area extends from the bay shore up to about elevation 90 feet. The 2.5 MG Francisco Reservoir, located on Russian Hill with an overflow elevation of 135 feet, lies adjace. to the northern portions of the University Mound pressure zone, but has been disconnected from this system since the early 1970's. The piping network schematic for the University Mound pressure zone is presented as Plates 1-N and 1-S.

A KYPIPES model of the University Mound pressure zone was supplied by the SFWD City Distribution Division. This model expresses flows and demands in gallons per minute (units of million gallons per day are used in the other models). The model was modified by LH for this study.

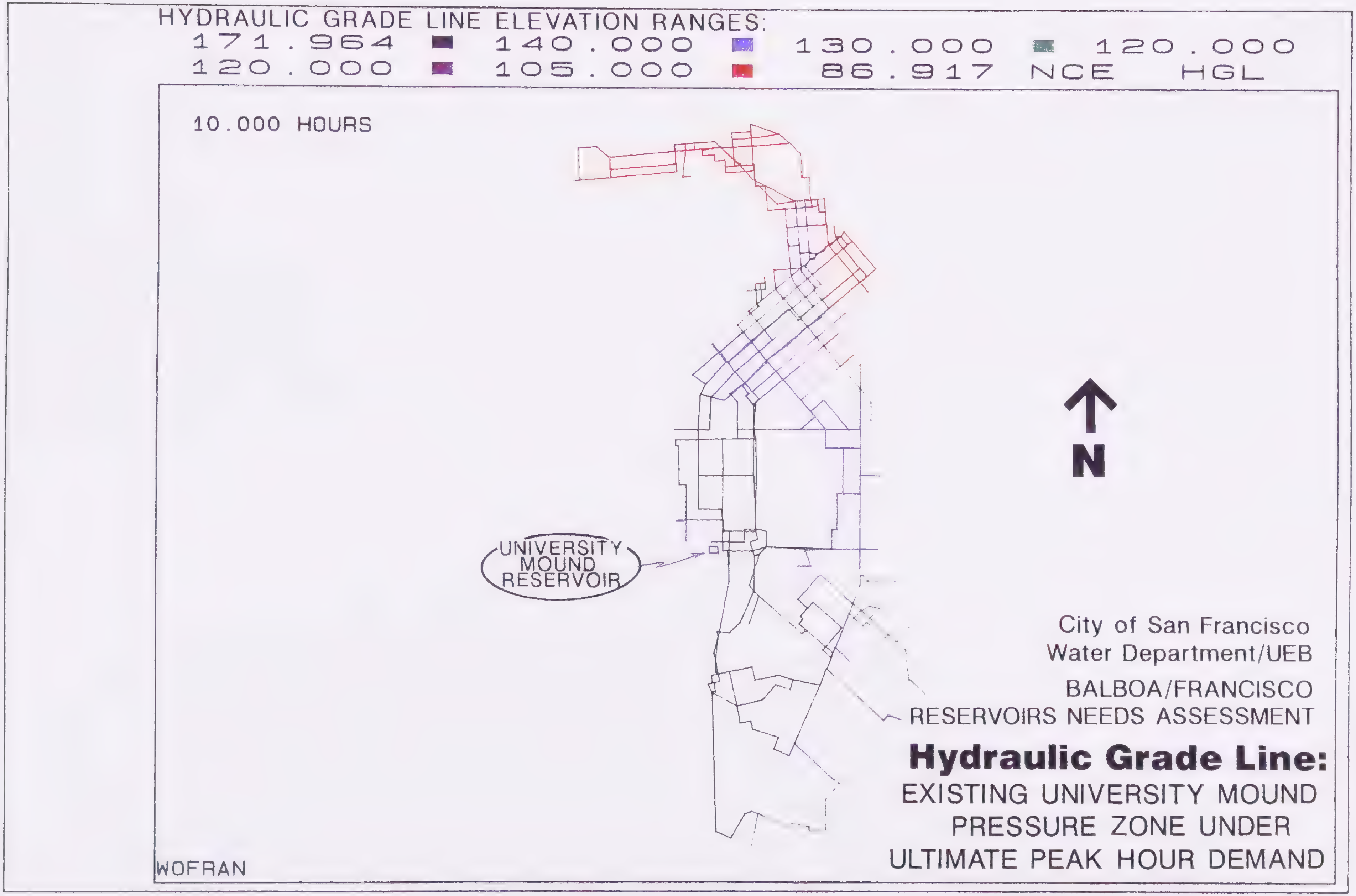
The University Mound system was first modeled to determine its capability to handle ultimate (year 2035) demands. Pipeline hydraulic friction C-factors and water demands were adjusted as described previously. The Treasure Island demand of 1.67 mgd (1160 gpm) was included as a point demand at node 144, the closest node to the Bay Bridge Pump Station. All demands were scaled up proportionately to the ultimate University Mound demand of 38.7 mgd (27,000 gpm).

It was not considered necessary to adjust the model to reflect future demands of the proposed Mission Bay development. Feeder lines in the area are sized for large industrial flows. The demands of the new housing/commercial complex are not expected to exceed previous industrial demands.

Results for existing University Mound piping network. The model for the University Mound pressure zone shows the system is adequate to handle ultimate average day demands. However, the model shows low pressures at the extreme end of the system in the Marina District during peak hour, and maximum day plus fire-fighting flow rates.

There is a significant head loss between the reservoir and the north end of the system. This loss of approximately 40 feet under the maximum day demand condition is distributed almost uniformly throughout the major transmission lines. The hydraulic grade line during peak hour demand is graphically illustrated in Figure 4-2, produced using the Stoner Associates LIQSS distribution system model.[4] Areas shown in red have hydraulic gradeline elevations less than 105 feet, adequate for 40 psi pressures only in areas below elevation 13 feet. Curves of daily pressure fluctuations at nodes 211 and 225 in the Marina District are shown in Figure 4-3.

[4] This work was performed at no cost to the City.



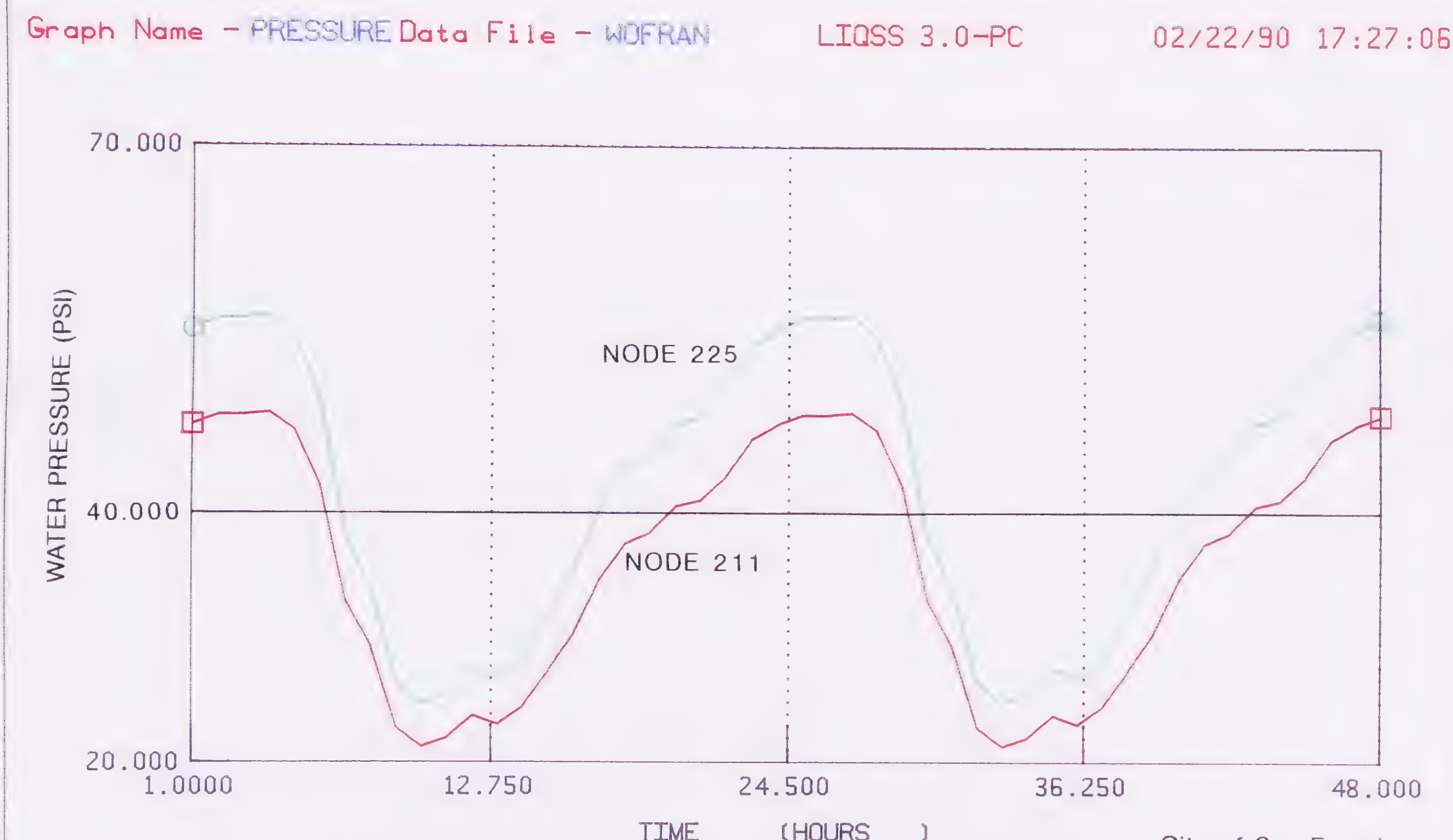
City of San Francisco
Water Department/UEB

BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Hydraulic Grade Line:
EXISTING UNIVERSITY MOUND
PRESSURE ZONE UNDER
ULTIMATE PEAK HOUR DEMAND

FIGURE 4-2

LEEDSHILL-HERKENHOFF, INC.



City of San Francisco
Water Department/UEB

BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Pressure Fluctuations
IN MARINA DISTRICT
WITH EXISTING SYSTEM UNDER
ULTIMATE MAXIMUM DAY DEMAND

FIGURE 4-3

LEEDSHILL-HERKENHOFF, INC.

At the extreme end of the system, there is a substantial head loss concentrated along Van Ness Avenue (designated pipe 339 on the distribution system schematic, Plate 1-N), Bay Street (pipe 341), Chestnut Street (pipe 342), and Lombard Street (pipe 343). All these pipes are of 16-inch diameter or less. C-factors are between 89 and 49.

As a check on this result, it was assumed that new piping of the same diameter was installed in place of these large transmission lines. When the C-factor of this piping is upgraded to 110, the areas with low pressures under peak hour and maximum day plus fire fighting demands still remain below acceptable pressures.

Since the low pressure area is located just below the Francisco Reservoir, additional model runs were made to determine the benefit of integrating Francisco Reservoir into the system. Four significant constraints exist:

- Under **average day demand**, the Francisco water surface elevation must be **greater** than the University Mound hydraulic grade line at the reservoir during the day, to <u>allow the reservoir to cycle</u> and prevent stagnation.

- Under **high demand conditions** (maximum day, peak hour or fire-fighting flow), the Francisco water surface elevation must **exceed** the present University Mound hydraulic grade line to <u>provide a pressure benefit</u>.

- Under night-time low demand conditions Francisco water surface elevation must be less than the University Mound hydraulic gradeline to allow <u>reservoir refilling</u>.

- Francisco Reservoir volume must be adequate to meet the full duration of a high demand, to <u>prevent draining the reservoir</u>. If the reservoir emptied, the system would revert to its present characteristics, with inadequate pressures in the Marina District.

Several solutions were considered for the University Mound pressure zone:

1) **Use of the existing Francisco Reservoir.** Hydraulic grade line elevations from University Mound are about 133.0 feet at Larkin & Bay Streets at the foot of Russian Hill under maximum day demand. Thus, minimal pressure benefit would be derived from re-connection of the existing 135-foot Francisco Reservoir to the system.

2) **Connection of an enlarged Francisco Reservoir to the University Mound pressure zone** and "raising" Francisco Reservoir to an overflow elevation of 172 feet to "float" on University Mound system. Such an arrangement would create an area of Francisco service extending from the Marina District to Market street, which includes most of Downtown. This would initially raise pressures under maximum day demand, but the reservoir would be drafted to serve the large Downtown demand and would soon be emptied. In this situation, the system would revert to its present characteristics, with inadequate pressures in the Marina and North Beach Districts.

3) **Connection to Sunset or Lombard pressure zone.** A simple solution to the low pressure problem would be installation of pressure reducing valves (PRVs) at connections to the Marina District from the Sunset pressure zone or its satellite, Lombard Reservoir. This sort of arrangement is presently done manually by opening divide valves from the Sunset zone to mitigate low pressures caused by fire fighting demands. The PRVs would automate this process, opening automatically whenever pressures drop below the desired pressure set points. Although this would raise all of the pressures within University Mound to adequate levels, it would result in lower pressures within the Sunset system during maximum day demands. In addition, a considerable energy expense would be incurred to pump additional water to the Sunset zone.

4) **Creation of a dedicated Francisco Reservoir pressure zone** with a raised reservoir. Such a pressure zone would increase pressures under maximum day demand conditions when the hydraulic grade line from University Mound pressure zone drops below the elevation of Francisco Reservoir. The reservoir could be sized to prevent emptying by restricting the service area, and would allow

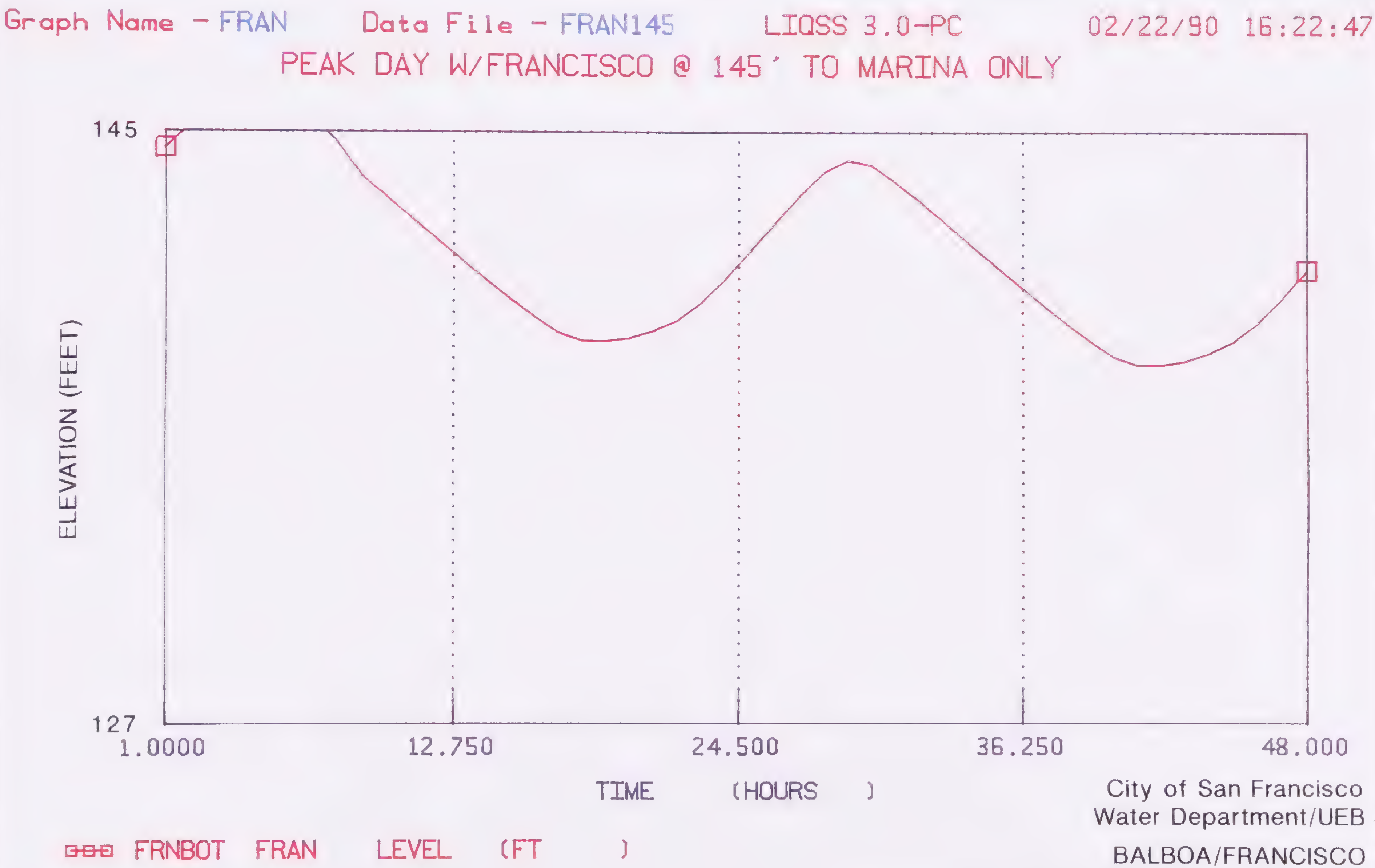
refilling from the gravity-supplied University Mound reservoir, eliminating additional pumping costs. This option is explored in some detail in the following section.

University Mound/Francisco System Models

A University Mound/Francisco system was modeled by creating two pressure zones from the existing University Mound zone. In this model Francisco Reservoir was used to supply the extreme end of the University Mound pressure zone located in the Marina District. This separate pressure zone would supply an ultimate (year 2035) average day demand of 2.2 mgd, or about six percent of the existing University Mound zone. The two mains serving the Marina District would be valved off from the University Mound service area directly north of the reservoir on North Point and Bay Streets. A check valve would be installed at Francisco and Hyde Streets (between nodes 227 and 228 on the model) to prevent back-flow towards University Mound. All flow to points west would be passed through Francisco Reservoir. With this configuration, Francisco Reservoir would serve the pressure zone under all demand conditions including fire-fighting flows and could refill from University Mound during night-time low demand periods.

Due to the dynamics of the two reservoirs in the system, an extended period simulation (EPS) model was required to analyze the reservoir system fluctuations over time. The EPS model was used to calculate the reservoir status every half hour for a 24 hour period using a daily demand curve. This demand curve was taken from the 1986-87 Pitometer Report on the University Mound demand.

Francisco maximum day demand models. A maximum day EPS model was run to determine the starting elevation to which Francisco Reservoir would refill at the end of a 24-hour maximum day demand period. The model suggests that during the 24-hour period, the water surface elevation would stabilize at about 145 feet and would draw down to about 138 feet at its lowest level. This result was confirmed using the Stoner Associates LIQSS model. Reservoir fluctuations over two consecutive maximum day demand periods is illustrated in Figure 4-4. A model was also run assuming that Francisco Reservoir floor area was expanded about 45 feet toward the toe of the hill. In this case the stabilized water surface elevation would be about the same, but with a drawdown to only about 140 feet.



City of San Francisco
Water Department/UEB

BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Water Surface Fluctuation
IN 145' FRANCISCO RESERVOIR
SERVING MARINA DISTRICT UNDER
ULTIMATE MAXIMUM DAY DEMAND

FIGURE 4-4

LEEDSHILL-HERKENHOFF, INC.

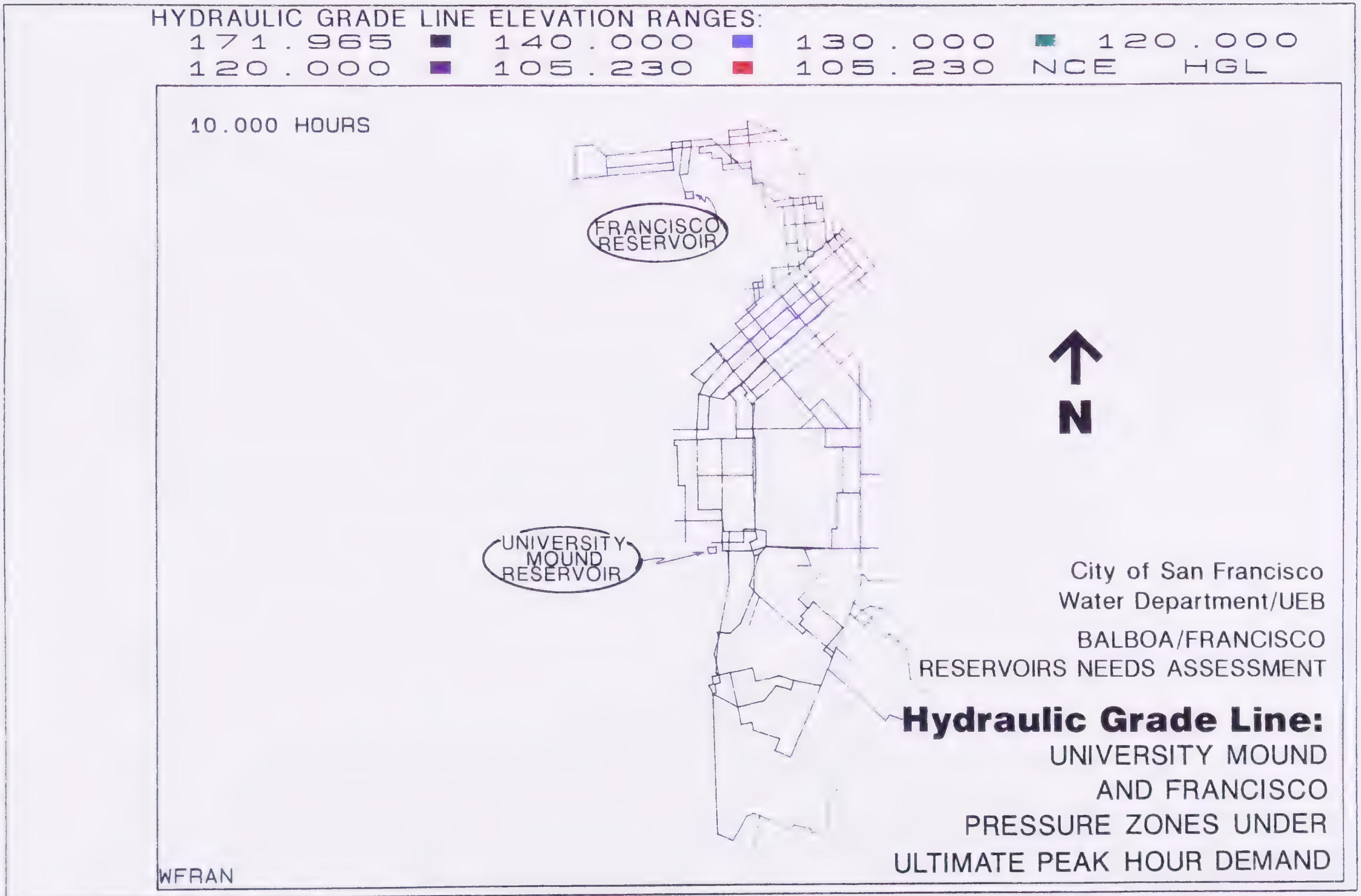
Low pressure problems in the Marina District would be eliminated by the addition of a Francisco Reservoir raised to an elevation of 145 feet. Since a portion of the University Mound demand would be handled by Francisco, the addition of Francisco also results in increased pressures in the University Mound pressure zone. These improved pressures are illustrated in the LIQSS plots presented as Figures 4-5 and 4-6.

Peak hour demand models. The results of the University Mound/Francisco Reservoir peak hour model run are plotted on Plates 1-N and 1-S. The addition of Francisco Reservoir would help significantly during peak hour demands. Nearly all of the Marina area experiences very low pressures during peak hour conditions with the existing system. With the addition of Francisco reservoir most pressures wouldbe raised above 30 psi. These pressures could be raised to levels above 40 psi if several lengths of pipe are upgraded as described below. These lines arepresently experiencing from 14 to 31 feet of head loss (4.3 to 9.5 feet of loss per 1000 feet) due to low C-factors and small diameters.

Fire flow models. Fire flow conditions were analyzed using both static and EPS models. The fire fighting demands consisted of two fires, a 12,000 gpm fire Downtown and a 4000 gpm fire in the Marina District.

Static fire flow models of the existing University Mound system indicate that there would be several very low pressures (essentially no pressure at street level) in the Marina District and generally low pressure throughout much of the University Mound zone.

An EPS model was then used to examine these fire flow conditions over a period of 12 hours with Francisco Reservoir attached to the system. This model indicated that although the addition of Francisco Reservoir helped raise the pressures significantly, pressures were still below the required 20 psi minimum residual pressure for fire fighting conditions.



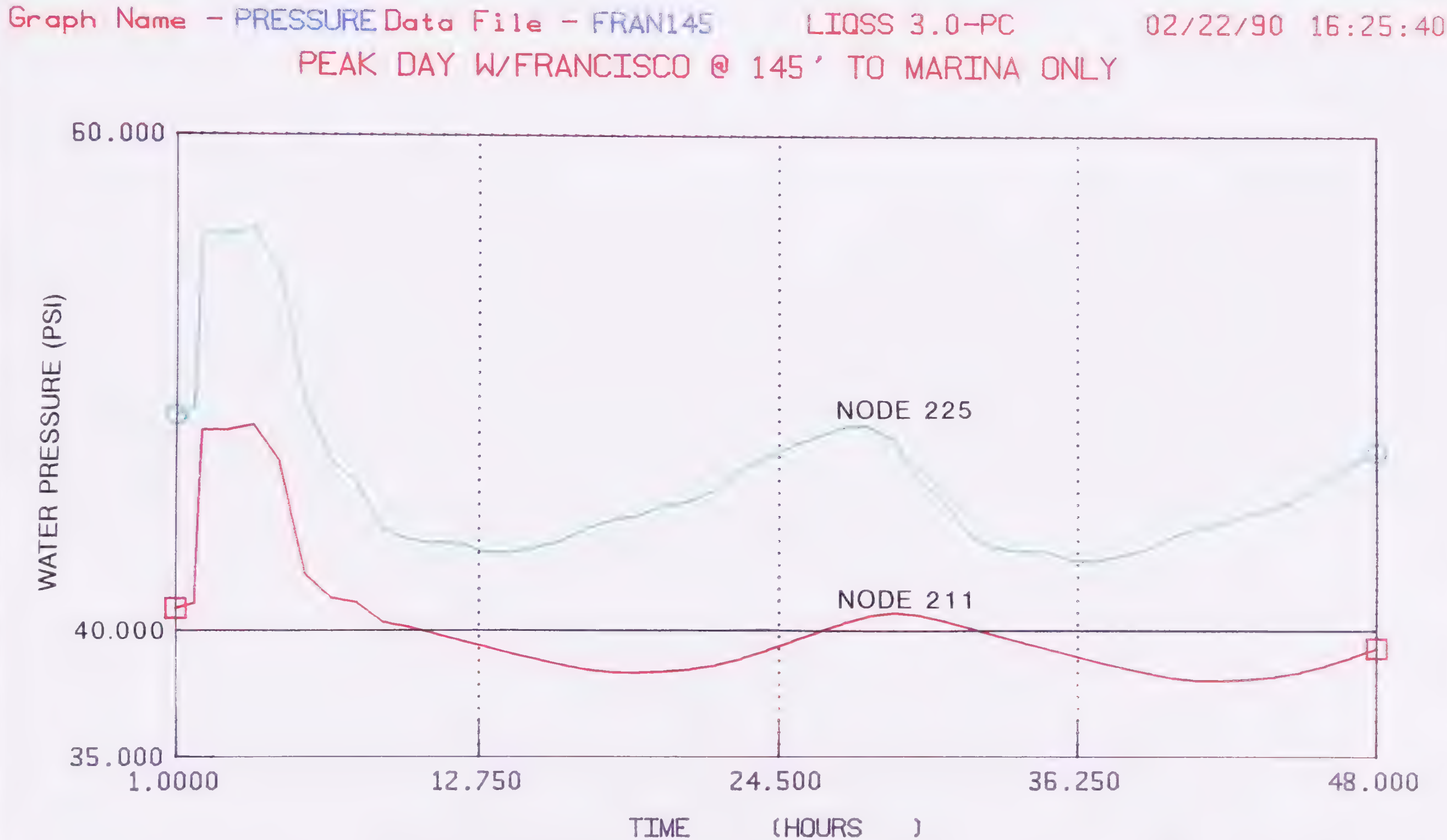
City of San Francisco
Water Department/UEB

BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Hydraulic Grade Line:
UNIVERSITY MOUND
AND FRANCISCO
PRESSURE ZONES UNDER
ULTIMATE PEAK HOUR DEMAND

FIGURE 4-5

LEEDSHILL-HERKENHOFF, INC.



City of San Francisco
Water Department/UEB

BALBOA/FRANCISCO
RESERVOIRS NEEDS ASSESSMENT

Pressure Fluctuations
IN MARINA DISTRICT
WITH FRANCISCO RESERVOIR UNDER
ULTIMATE MAXIMUM DAY DEMAND

LEEDSHILL-HERKENHOFF, INC.

FIGURE 4-6

__Remedial piping__. In order to adequately raise low pressures in the Francisco pressure zone during fire fighting conditions, pipe replacements were considered. It was found that if two lengths of pipe totaling 5700 feet were replaced, residual pressures could be raised to above 20 psi. These two pipes run in series in the Marina District, starting on Bay Street and continuing down Beach Street to Baker Street. On the model these pipes are numbered 341 and 346. The two pipe sections are 12 inches in diameter and have C-factors of 63. To raise the pressure to 20 psi under fire fighting conditions, new 16-inch lines are necessary.

Thus, by creation of a separate pressure zone for Francisco Reservoir, along with the replacement of 1.1 miles of piping, low pressure problems in the Marina District during peak hour and fire fighting conditions are remedied. In addition, there are slight increases in pressures throughout the University Mound zone.

The proposed solution involves valving-off the Marina District from the University Mound pressure zone at two locations. One valve would be on the pipeline along North Point Street between Polk and Larkin and the other would be at Bay Street also between Polk and Larkin. On the model these pipelines are represented by pipe numbers 334 and 335. From Bay and Larkin a line would connect the University Mound zone directly to Francisco Reservoir. A check valve would be added to allow flow to Francisco and to prevent back-flow. Connection to the reservoir would be made with 800 feet of 24-inch pipe. Francisco Reservoir would be attached directly to the valved-off zone using another 800 feet of 24-inch diameter pipe. Plumbed this way all water entering this new zone would have to pass thorough Francisco and thus would allow it to cycle. The costs for these modifications are detailed in Table 4-3, and total about $755,000.

Table 4-3

Cost Tabulation For Remedial Piping
University Mound/Francisco Pressure Zone

Item	Diameter	Location	Qty	Unit	Unit	Total
Gate Valve	24	Polk & Bay	1	EA	$14,300	$ 14,300
Gate Valve	16	Polk & North Point	1	EA	5,375	5,375
Check Valve	20	Francisco & Larkin	1	EA	13,100	13,100
CI Pipe	24	Bay & Francisco	800	LF	106	84,800
CI Pipe	24	Larkin & Polk	800	LF	106	84,800
CI Pipe	16	Along Bay	3300	LF	97	320,000
CI Pipe	16	Along Beach	2400	LF	97	233,000
						$755,375

Notes: Valve costs estimated from Means Cost Estimating Guide.
Pipe costs estimated from SFWD

The existing reservoir would be raised to about elevation 145 feet. This would result in a 5.8 million gallon reservoir, using the footprint of the existing reservoir. At the greatest drawdown resulting from a maximum day demand, 3.5 MG would remain in storage. About 2.9 MG are required for fire fighting reserve. Remote electrically controlled valves on the piping from the University Mound system could be added to allow Francisco to supplement Downtown fire fighting demands.

DISTRIBUTION SYSTEM IMPROVEMENTS

The varying topography and gridded street system of the City makes the task of providing optimal pressure zone boundaries with acceptable pressures under all flow conditions difficult. Although the present pressure zones do a good job under normal demands, rearrangement of the zone boundaries or creation of a new Balboa or Francisco pressure zone may be helpful to solve high demand problems.

Presently most of the low pressure problems occur only in small, isolated areas or on the fringes of existing pressure zones. As demands rise, head losses increase and these low pressure areas expand. To remedy these problems, the problem areas should be adopted into adjacent pressure zones of higher elevation. It is possible to do this by re-piping parts of the zones, adding new pressure zones such as Balboa or Francisco, or by extension of pipelines from higher pressure zones.

Sunset Service Area Boundaries

The KYPIPES model results of the Sunset system show that both high and low pressure problems occur within the pressure zone. Most of these pressure problems appear to be in either isolated areas or on the outer fringes of the zone.

The major low pressure region is in the north east portion of the pressure zone. This area of low pressure is bordered by O'Farrell and Green Streets to the north and south and Fillmore and Stockton Streets to the east and west. Their low pressures are a result of both high elevation and inadequate piping. Due to the elevation constraint in this area (parts above 300 feet) it would not be possible to remedy the situation using the 312-foot Balboa Reservoir. However it may be possible to expand the Sutro pressure zone (500-foot service) to remedy these low pressures.

High pressure areas occur in several regions throughout the Sunset pressure zone. Some high pressures are found on the lower fringes of the zone east of Twin Peaks. In order to eliminate these pressure problems it may be possible to implement a Balboa service area that would be the intermediate zone between the 255-foot College Hill and the 385-foot Sunset systems. This area is served by a pair of north-south pipelines in the Sunset pressure zone, one of which could be dedicated to Balboa service. Such an arrangement could create problems as well; looping of the Sunset system would be reduced, and deliveries to the Sunset-served Potrero Hill Reservoir would be limited. Alternatively, the displaced fringe areas in the Sunset zone could be served from the 500-foot elevation Sutro Reservoir.

University Mound Service Area Boundaries

The University Mound pressure zone experiences some pressures below the desired 40 psi. These low pressures occur during maximum day, peak hour and fire fighting demands when using the ultimate city demand of 110.5 mgd. The largest area experiencing these low pressures is the extreme north-western portion of the pressure zone beginning west of Larkin Street and covering a 45 block area of the Marina district. Models representing peak hour demand show pressures as low as 6.3 psi on the extreme west end of the Marina district. The high pressures in this area under these same conditions were all below 18 psi.

Within the University Mound area there are two major pipelines. Both start north from the reservoir as 48-inch pipes, and are eventually reduced to 24-inch diameter at the far northern end of the zone. Upgrading these lines is not considered a solution to the low pressure problems due to the lengths involved and the uniform losses through these lines.

Only the 385-foot service Sunset and 303-foot service Lombard pressure zones are adjacent to the Marina. Sunset feeds Lombard, and itself experiences low pressures under high demand conditions. Use of these zones to serve this 40-foot elevation area would include a considerable waste of energy and would further reduce pressures in the Sunset and Lombard pressure zones. Creation of a Francisco pressure zone as described above is the recommended alternative.

Source Interruption or Storage Out of Service

There may be any number of scenarios in which supply could be interrupted within the City's water distribution system. Transmission of water is dependant upon all system components including reservoirs, pipe lines, treatment plants, and pumping stations. A failure of any one of these due to power outages, line breakage, earthquake, or mechanical failure would require finding alternative sources of supply to serve the areas involved. The Sunset, College Hill and University Mound Systems are analyzed below to determine what alternative supplies are available. Reference to Figure 2-1 will aid in the following discussion.

Sunset Reservoir. Several situations may occur that would result in a reduced supply to Sunset Reservoir. Failure of the Crystal Springs bypass tunnel, Crystal Springs pipelines, Sunset supply line, or a failure of the Lake Merced Pump Station could all result in a loss of supply. If such a failure were to occur several possible alternative sources would be available:

- **Supply Sunset pressure zone from reserve storage.** For short term supply conditions it may be possible to serve the Sunset area from emergency reserves. Together with its satellite reservoirs, Lombard and Potrero, Sunset Reservoir has a 3.6 day reserve supply.

- **Supply Sunset from the 54-inch San Andreas pipeline.** This could be done by fully opening the San Andreas Pipeline valve at the San Pedro valve lot[5]. Reference to Table 2-6 shows that a total flow capacity of 55.3 mgd is required to serve the College Hill pressure zone, and the Sunset pressure zone and its satellite reservoirs. The rated capacity of the 54-inch San Andreas line is approximately 47.0 mgd, and thus can not handle the entire demand. However, the balance could be supplied from storage for up to 24 days.

- **Alemany Pump Station.** The 42.0 mgd demand of Sunset pressure zone and its satellite reservoirs could be fully met from the San Andreas pipeline if the 13.3 mgd College Hill demand is met from the 41.0 mgd Alemany Pump Station. Total demand of College Hill and University Mound pressure zones could be accommodated through the 57.0 mgd capacity Crystal Springs pipelines.

- **Supply Sunset with San Andreas pipeline, supply College Hill with Balboa Reservoir.** Balboa Reservoir could be used to supply the College Hill zone, eliminating the need to pump at Alemany. The 54-inch San Andreas line would be used to serve the Sunset zone.

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5 The 1989 CDM study shows minimal head losses from the San Andreas Water Treatment Plant finished water reservoir to Sunset Reservoir if flows through the 54-inch San Andreas pipeline are not throttled.

College Hill Reservoir. As diagramed in Figure 2-1, the supply to College Hill Reservoir is conveyed through the Pulgas Tunnel, the Crystal Springs Reservoir and Pump Station, the San Andreas Reservoir and water treatment plant, and through several large pipelines including the 54-inch San Andreas line. Problems or failures with any if these pump stations, reservoirs or transmission pipelines could result in the interruption of flow to College Hill Reservoir. In addition, provision must be made to meet the College Hill service area demand when the single-basin reservoir is removed from service for cleaning.
Under a source interruption condition, several alternative supply sources could be used:

- **Supply College Hill from Sunset Reservoir.** If flow through the San Andreas pipeline ceased, flow would continue to flow to the College Hill pressure zone from Sunset Reservoir. These pressure zones are connected by the Crosstown pipeline. Sunset pressures are reduced to College Hill pressures at the Roanoke PRV station. A total average day demand of 64.2 mgd is required for College Hill plus the zones normally fed by the 57.0[6] mgd capacity Sunset supply line. Sunset Reservoir has storage capacity to make up the supply deficit for about 24 days.

- **Supply College Hill Reservoir with Alemany Pump Station.** College Hill Reservoir could be served from University Mound Reservoir using the Alemany Pump Station. With a capacity of 41.0 mgd, Alemany Pump Station could easily supply the 13.3 mgd College Hill demand. Total average day demand on the Crystal Springs pipelines from College Hill and University Mound would be 49.8 mgd, capacity of these pipelines is 57.0 mgd[7].

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[6] SFWD Data Book, page 75

[7] SFWD Data Book, page 75.

- **Supply College Hill from Balboa Reservoir.** Balboa Reservoir could provide a direct, gravity-fed supply in the event of a failure of the College Hill supply system. Emergency reserves of other pressure zones would not be tapped, and additional pumping would not be necessary. Reliance on Alemany Pump Station would be minimized.

University Mound Reservoir. In the event of failure of the Crystal Springs Bypass Tunnel or the 60-inch and 44-inch Crystal Springs pipe lines, the supply to University Mound Reservoir would be interrupted. In such an event it would be necessary to find an alternative source of supply. The only alternative source of potable water delivery is from San Andreas or Sunset Reservoirs via the 36- and 44-inch diameter Crosstown pipe line.

Although storage and potential supply capabilities exist within the system (Sunset Reservoir storage supplied through the 54-inch San Andreas line) there is a constraint on this alternative due to a maximum capacity of 51.0 mgd[8] in the Crosstown pipe line. Under ultimate demand conditions, the average day capacity that would be required from this line would be 53.0 mgd. This demand includes College Hill (13.3 mgd) and University Mound (38.7 mgd) systems along with the demand of Sunset off of the Crosstown line (1.1 mgd). Thus the pipeline does not have the capacity to handle maximum day demands.

Integration of Francisco Reservoir into the University Mound System would reduce the demand on University Mound by 2.2 mgd. If the proposed check valves between the Francisco and University Mound zones were opened under source interruption conditions, Francisco Reservoir, particularly an enlarged reservoir, would help meet University Mound peak demands. Enlargement of the connection between the Sunset and Francisco zones would provide a secondary supply route to University Mound, without use of the Crosstown pipeline.

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[8] SFWD Data Book, page 49.

Further improvement in alternative University Mound supply would occur if Balboa Reservoir was on line. Balboa could supply College Hill and University Mound Reservoirs, with Sunset supplying the northern portions of the University Mound service area through Francisco Reservoir.

OPERATION AND MAINTENANCE COSTS

As a result of the high degree of reservoir interconnection, water can be supplied through several different routes. In order to determine the cost efficiency of supplying each reservoir through one or more of these routes, unit cost estimates for each transmission option were made. Operation costs are primarily composed of pumping and treatment costs.

The pumping cost was determined by adding the static head to friction losses to determine the total pumping head required. The friction losses were estimated from either CDM or LH modeling results. An energy cost of $0.07/kWh[9] was used.

Treatment costs were added if water was transported through the San Andreas Water Treatment Plant. Treatment costs were estimated to be from $85 to $90 per million gallons by SFWD. Operation costs of the various supply routes are presented in Table 4-4.

Balboa or College Hill Reservoirs could be supplied through Sunset Reservoir via the Lake Merced Pump Station at a cost of $47 to $56 per million gallons. College Hill could be supplied most inexpensively from the Alemany Pump Station for $24 to $33/MG. Both the Sunset and Alemany routes will increase by about $85/MG once the Crystal Springs Water Treatment Plant is on-line. This is still less expensive than the current San Andreas source of supply[10].

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[9] Average cost of 1988-89 pumping at Crystal Springs and Lake Merced pumping plants. Data from Hetch Hetchy Bureau of Light, Heat and Water

[10] Natural runoff from the San Andreas watershed is not considered.

Table 4-4

Water Transmission Options and Costs

	Static Head (ft)	Pipe Lose (ft)	Pump Head (ft)	Treat-ment	Total Cost[2] ($/MG)
<u>Supply to Sunset</u>	213	13	226	N	$ 62
C.S. pipeline/Alemany P/S	245	14	259	N	71
C.S. pipeline/Alemany P/S[1]	181	12	193	Y	138
San Andreas pipeline/C.S. P/S	166	5	171	N	47
Sunset pipeline/Lake Merced P/S	198	6	204	N	56
Sunset pipeline/Lake Merced P/S[1]					
<u>Supply to College Hill</u>	83	5	88	N	$ 24
C.S. pipeline/Alemany P/S	115	6	121	N	33
C.S. pipeline/Alemany P/S[1]	181	12	193	Y	138
San Andreas pipeline/C.S. P/S	166	5	171	N	47
Sunset pipeline/Lake Merced P/S	198	6	204	N	56
Sunset pipeline/Lake Merced P/S[1]					
<u>Supply to Balboa</u>	140	7	147	N	$ 40
C.S. pipeline/Alemany P/S	172	8	180	N	49
C.S. pipeline/Alemany P/S[1]	181	12	193	Y	138
San Andreas pipeline/C.S. P/S	166	5	171	N	47
Sunset pipeline/Lake Merced P/S	198	6	204	N	56
Sunset pipeline/Lake Merced P/S[1]					

Notes:
[1] Includes pumping through Crystal Springs Balancing Reservoir
[2] Treatment Costs @ $85/MG, Energy @ $0.07/kWh
Ct+Ce($/MG)=Ct+(head)($/kWh)3.14(1/e). e=0.8

Balboa Reservoir could be supplied least expensively by the Alemany Pump Station. Supplying Balboa from the Alemany Pump Station would require installation of a 36-inch pipeline parallel to the Crosstown pipeline along Circular Avenue. This line connects the 44-inch segment of the Crosstown pipeline from Alemany with the

Balboa Reservoir. This new pipe would be used both to fill and draft the reservoir. A branch line to the Roanoke PRV station would supply the College Hill pressure zone. The southern portion of the College Hill pressure zone would be valved-off and supplied directly from Balboa. The existing 36-inch Crosstown pipeline would be used exclusively for Sunset 385-service.

Balboa could be supplied by either Alemany Pump Station or Sunset Reservoir. It would require approximately 12,200 feet of 36-inch pipe to make this connection at a cost of $3.0 million, as shown in Table 4-5.

Table 4-5

Cost Tabulation For Connection
of Alemany Pump Station to Balboa Reservoir

Item	Diameter	Location	Qty	Units	Unit	Total
Steel Pipe	36	Circular Ave.	1500	LF	$284	$426,000
Steel Pipe	36	Circular Ave.	7000	LF	244	1,708,000
Steel Pipe	36	Natick St.	300	LF	244	73,200
Steel Pipe	36	Chenery St.	2450	LF	244	597,800
Steel Pipe	36	Fairmont St.	450	LF	244	109,800
Steel Pipe	36	Roanoke Vault	500	LF	244	122,000
					Total	$3,036,800

* Unit cost estimate for pipe from SFWD bid report and 1990 Means Cost Estimate Data

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations from the study are presented below. Two types of benefits were identified and evaluated: the ability of Balboa or Francisco Reservoir to relieve existing pressure or flow problems, and the need for additional emergency storage.

BALBOA RESERVOIR

The two Balboa Reservoir basins are located near San Francisco City College on Ocean and Phelan Avenues. When filled, the total capacity of the reservoirs would be 150 million gallons at an overflow elevation of 312 feet. The two asphalt-concrete lined basins have never been used for water storage. The north basin is presently used as a parking lot for the College. There is a pipe connecting the two basins, but no supply or service lines are connected to either basin. The elevation of the reservoir would permit service to portions of the Sunset and College Hill pressure zones.

Recommended Alternative

LH/AGS recommend renovation and roofing of a single Balboa Reservoir basin with a piping connection to the City system. Insufficient soils information for the south basin does not allow recommendation of a particular basin. It is recommended to supply Balboa Reservoir from Alemany Pump Station, and to use the reservoir to supply the College Hill pressure zone.

Pressure Benefits

In normal operation, **Sunset Reservoir** is filled primarily from the Crystal Springs Bypass and the Sunset Supply pipeline via the Lake Merced pump station. The San Andreas pipeline, also connected to the Sunset system, is throttled back to Sunset pressure at the San Pedro valve lot, and directly serves the southern

portion of the Sunset service area. The Sunset pressure zone has a direct connection to College Hill Reservoir through the Crosstown pipeline. Sunset directly serves Lombard and Potrero Reservoirs.

Piping and pressures are inadequate to meet maximum day, peak hour and fire fighting demands in a large area in the **northeast portion** of the Sunset pressure zone around Pacific Heights and Nob Hill. Water cannot be delivered to Lombard Reservoir under maximum day demand. Part of the reason for the low pressures in this northeast section is the large hydraulic head loss in the four supply mains extending from the western part of the service area[1]. To alleviate this, remedial piping totaling $3.1 million are required. Using Balboa to resolve low pressures in the northeast portion of the Sunset pressure zone <u>is not</u> an alternative solution. The Sunset hydraulic grade line near Balboa Reservoir under maximum day demand is 365 feet. Maximum Balboa elevation is 312 feet.

College Hill Reservoir is supplied from the San Andreas and Crosstown pipelines through the Roanoke PRV station. College Hill's total demand is about 12 percent of the total City demand, or 13.3 mgd. Pressures are generally adequate, except in:

- the portion of the pressure zone **south of the reservoir** under maximum day, peak hour, and fire fighting demands;

- the northwest portion of the zone in the **Western Addition** under maximum day, peak hour, and fire fighting demands; and

- the **Downtown/Chinatown** portion of the service area under fire fighting demands.

The area **south of the reservoir** has low pressures under maximum day, peak hour and fire fighting demands, due partly to 6-inch diameter, high-headloss piping. Direct service from Balboa Reservoir would mitigate these problems.

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[1] Pipes 119, 120, 131, and 132 along California, Geary, Oak, and Haight Streets, respectively. Refer to the distribution system schematic.

Areas in the extreme northwest of the zone in the **Western Addition** also have low pressure problems. Much of the area is served by 6-inch diameter piping, pipe looping is poor and elevations are generally above 110 feet[2]. A tie-in to the neighboring Sunset pressure zone, which also has low pressure problems, will not solve the pressure problems. Installation of 15,600 feet of new pipelines would remedy the peak hour and fire fighting pressure problems. The incorporation of Balboa Reservoir could be used to mitigate low pressures in the Western Addition area and other low pressure regions on the fringe of the College Hill pressure zone. However, the re-piping of the Sunset and College Hill zones necessary to service the Western Addition from Balboa would be very expensive and is not recommended without further study.

Fire-fighting flow rates of 12,000 gpm are required in the northeastern part of the zone, which includes parts of **Downtown and Chinatown**. This demand cannot be met with existing piping. Pipes in this area are old, 12 to 16 inches in diameter, and have low C-factors. A 24-inch diameter pipeline would be required, even with the higher pressures that could be provided by Balboa Reservoir. Alternatively, fire fighting demands can be met by continuing the practice of opening divide valves from the Sunset pressure zone during fire conditions, and reliance on the High Pressure Supplementary System fire supply.

Storage Benefits

Fire-fighting flow rates in the College Hill pressure zone would require nearly 13 million gallons of storage, a volume approximately equal to that of College Hill Reservoir. Balboa Reservoir would ensure adequate fire fighting, emergency, and operational storage for the College Hill zone.

City-wide, there is an average 3.0 days of storage reserve under ultimate average day demand. The major storage reservoirs are well connected by pipelines and pumping plants that enable most demands to be met in the event of a failure in the source of supply, or the need to take a reservoir out of service for maintenance.

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[2] About 60 psi static pressure for service from College Hill 255-foot service.

In the event of a major emergency, the City could be cut off from the source of supply for one to two weeks. Assuming strict rationing, normal demands could be cut in half. It is therefore prudent to endeavor to provide three and one-half to seven days of potable, gravity-fed storage at average day demand for such an emergency situation.

The College Hill pressure zone emergency storage reserve is currently equal to 2.9 days of average use when supplemented by Sunset Reservoir. University Mound pressure zone has a 3.3 day reserve. Reserves for these zones could be increased to 3.8 days of storage with the addition of one Balboa basin, or to 5.0 days of storage with both Balboa basins. Unburdened of supplying College Hill emergency storage, Sunset storage reserve would increase from 2.9 days to 3.6 days. City-wide reserves would be expanded from 3.0 days to 3.6 days or 4.1 days using one or both basins, respectively.

It is recommended that Balboa be used to serve the entire College Hill pressure zone. The portion of the zone south of the reservoir would be served directly from Balboa Reservoir, with the remainder fed through College Hill Reservoir.

Although it appears beneficial to incorporate both Balboa basins into the City distribution system, this storage needs to be circulated on a regular basis. Water in storage should be circulated about once a week to avoid stagnation. The demand of the College Hill pressure zone would circulate one Balboa basin once every 5.6 days, but both basins could be circulated only once every 11.3 days. Unless it is acceptable to spill Balboa storage to the University Mound pressure zone, use of only a single Balboa basin is reasonable.

It is recommended to use one Balboa basin, served via the Crystal Springs pipelines and the Alemany Pump Station[3]. Connection of Balboa to the Alemany Pump Station would require 12,200 feet of 36-inch water main paralleling the Crosstown pipeline in Circular Avenue. Installation of this main would cost about $3.0 million. Modifications to Alemany Pump Station to provide emergency power will be required at additional cost.

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[3] Once the Crystal Springs Treatment Plant is on-line, Balboa may be supplied through the San Andreas and Crosstown pipelines at comparable costs.

Structural and Geotechnical Feasibility

Finite element analyses were made to evaluate the dynamic response of the Balboa Reservoir embankment to the maximum credible earthquake. This earthquake is of 8.3 Richter scale magnitude occurring on the San Andreas fault. The results of these analyses indicate that a zone of embankment soils in the southwest corner of the north basin is liquefiable under the maximum credible earthquake. To mitigate the liquefaction potential, either the reservoir should be lined or the liquefiable soils grouted.

The proposed Balboa Reservoir south basin roof design has been evaluated and found to be satisfactory. The cost to install the roof will be approximately $24.1 million.

Estimated Costs

Total cost for rennovation, roofing, and piping connections for a single basin is estimated at $27.1 million, exclusive of upgrades to Alemany Pump Station.

FRANCISCO RESERVOIR

The area formerly served by Francisco Reservoir is now part of the University Mound pressure zone. University Mound Reservoir, located in the southeastern part of the City, is comprised of two basins with 140.1 MG of total storage and an overflow elevation of 172 feet. University Mound serves eastern portions of the City including China Basin and Downtown, and northern portions including North Beach and the Marina District. The service area extends from the bay shore up to about elevation 90 feet. The 2.5 MG Francisco Reservoir, located on Russian Hill with an overflow elevation of 135 feet, lies adjacent to the northern portions of the University Mound pressure zone, but has been disconnected from this system since the early 1970's.

Recommended Alternative

Reconstruction of Francisco Reservoir with a storage capacity of 5.8 MG and a reservoir overflow at elevation 145 feet to serve a new Francisco Reservoir pressure zone is recommended.

Pressure Benefits

Distribution piping in the Marina District, at the extreme end of the University Mound pressure zone, performs adequately under average day demands, but was found to have low pressures under maximum day, peak hour, and fire fighting demands. Using both static and dynamic models it was determined that this area would be best served by creation of a separate pressure zone served by Francisco Reservoir. The reservoir would be refilled by gravity flow from the University Mound pressure zone during low demand (night-time) periods.

Computer modeling of the University Mound/Francisco system showed that creation of a dedicated Francisco pressure zone with the reservoir overflow raised to elevation 145 would increase pressures during high demand periods in both the new Francisco Reservoir pressure zone and in portions of the University Mound pressure zone. Francisco Reservoir would supply only the Marina District. This separate pressure zone would supply and ultimate maximum day water demand of 2.2 mgd, or about six percent of the existing University Mound demand. Since a portion of the University Mound demand would be handled by Francisco, the addition of Francisco results in increased pressures in the University Mound pressure zone. Check valves would be installed to allow reservoir refilling by gravity flow from the University Mound zone during low demand periods, and to prevent back-flow to the University Mound zone during high demands. Addition of a Francisco Reservoir raised to an elevation of 145 feet would eliminate low pressure problems in the Marina District, except under fire fighting demands.

Existing University Mound service to the Marina provides very low pressures (essentially no pressure at street level) under fire fighting demands. Addition of Francisco Reservoir would raise pressures significantly, but some would remain below the required 20 psi minimum residual pressure during fire fighting demand.

In order to adequately raise low pressures in the Francisco pressure zone during fire fighting conditions,installation of 5700 feet of new pipe is required.

Emergency Storage Benefits

At present, the Marina District is supplied by the University Mound Reservoir, which provides 3.3 days of reserve storage[4]. Raising Francisco Reservoir to an overflow elevation of 145 feet would provide about 5.8 million gallons of storage, using the footprint of the existing reservoir. This would provide an additional 2.1 days of storage for the Marina District. At the greatest drawdown resulting from a maximum day demand, 3.5 MG would remain in storage. About 2.9 MG are required for fire fighting reserve. Remote electrically controlled valves on the piping from the University Mound system could be added to allow Francisco to supplement Downtown fire fighting or emergency supply requirements, but are not included in the estimated cost.

All water provided to the Marina would be passed through Francisco Reservoir, allowing an average 2.6-day residence time thus preventing stagnation.

Structural and Geotechnical Feasibility

To derive pressure benefits, and to achieve compatibility with the present water system hydraulics, the existing reservoir would be raised to about 145 feet. Insufficient geotechnical data for the site are available for a definitive analysis. If the site is geotechnically sound, the height of the berms would be raised ten to fifteen feet, and the brick lining replaced by a concrete slab. The entire deck, roofing, columns, and foundation would be replaced with a concrete structural system.

[4] with reservoir drawn down to 80% capacity, normal minimum operating level.

Estimated Costs

The estimated cost to upgrade the Francisco Reservoir is at least \$4.3 million, exclusive of utility work, drainage, or other site improvement costs. Additional costs may accrue once the final design configuration has been determined, and due to the limited size of the site and its hillside location. An additional \$0.8 million of piping improvements are also recommended to meet fire fighting requirements in the Marina District.

RECOMMENDED ADDITIONAL STUDIES

This assessment of the Balboa and Francisco Reservoirs provides City decision-makers with essential basic information. The data and analyses presented herein reflect a considerable effort expended over a fifteen-week period. To further define the issues and constraints involved, LH/AGS recommend the following additional studies.

Demand distribution studies. The best data available for this study quantifying the City-wide distribution of demand are random measurements made over a 28-year period by Pitometer Associates. Additional data on metered flows from various pipelines and reservoirs are available from the computerized billing system of the SFWD Customer Service Division. These data were requested, but were not available in time to be incorporated into this study. These data may allow a more definitive demand distribution determination.

Hydrant tests. Only limited data are available for calibration of the distribution system models. These data include pressure readings at the Roanoke PRV station, and hydrant test data measured by ISO in 1965. Modeling accuracy and confidence could be greatly improved by making a set of hydrant flow tests, and using these data to calibrate the models (primarily adjustments of pipe roughness). Typically ten to fifteen points can be measured during the low-demand hours between midnight and five a.m. to obtain information on pipeline friction and overall flow characteristics of the system tested.

Dynamic modeling. Steady-state analysis of the water distribution system can not show reservoir and pressure fluctuations over the course of the day. Upgrading these models to dynamic, extended period simulation models will reveal significantly more about required reservoir capacities, supply source demands, and fire flow response. A dynamic model was developed for the University Mound/Francisco pressure zone to determine what elevation Francisco Reservoir could be refilled to after a peak day demand. Leedshill-Herkenhoff has developed expertise in both the KYPIPES and LIQSS (Stoner) models. Dynamic modeling using the LIQSS model should be considered because of its ease of input, graphical interpretation of output, and ability to produce computer-generated maps of the distribution system and model results through a plotter interface. KYPIPES input files are easily convertible to LIQSS input files.

SCADA feasibility. Operation of the City's distribution system could be much improved through implementation of a Supervisory Control and Data Acquisition system (SCADA). Such a system would measure pressures and flows throughout the system, and allow remote control of valving and pump equipment to optimize operation and minimize operation costs. LH personnel would be pleased to discuss SCADA feasibility with City staff.

Geotechnical investigations. The geotechnical evaluations for Balboa Reservoir were made based on the limited subsurface data available from previous studies. If the grouting alternative is selected as the liquefaction mitigation measure, additional subsurface exploration and laboratory testing will be required to further evaluate the limits of the medium dense soils in the embankments of the northern basin.

The geotechnical evaluations for Francisco Reservoir were made based on the available geotechnical and geologic data in the vicinity of the site. No site-specific geotechnical information was available at the time of the study. Additional geotechnical study including field exploration and laboratory testing will be required to evaluate subsurface conditions and develop site-specific geotechnical conclusions and recommendations for the proposed improvements.

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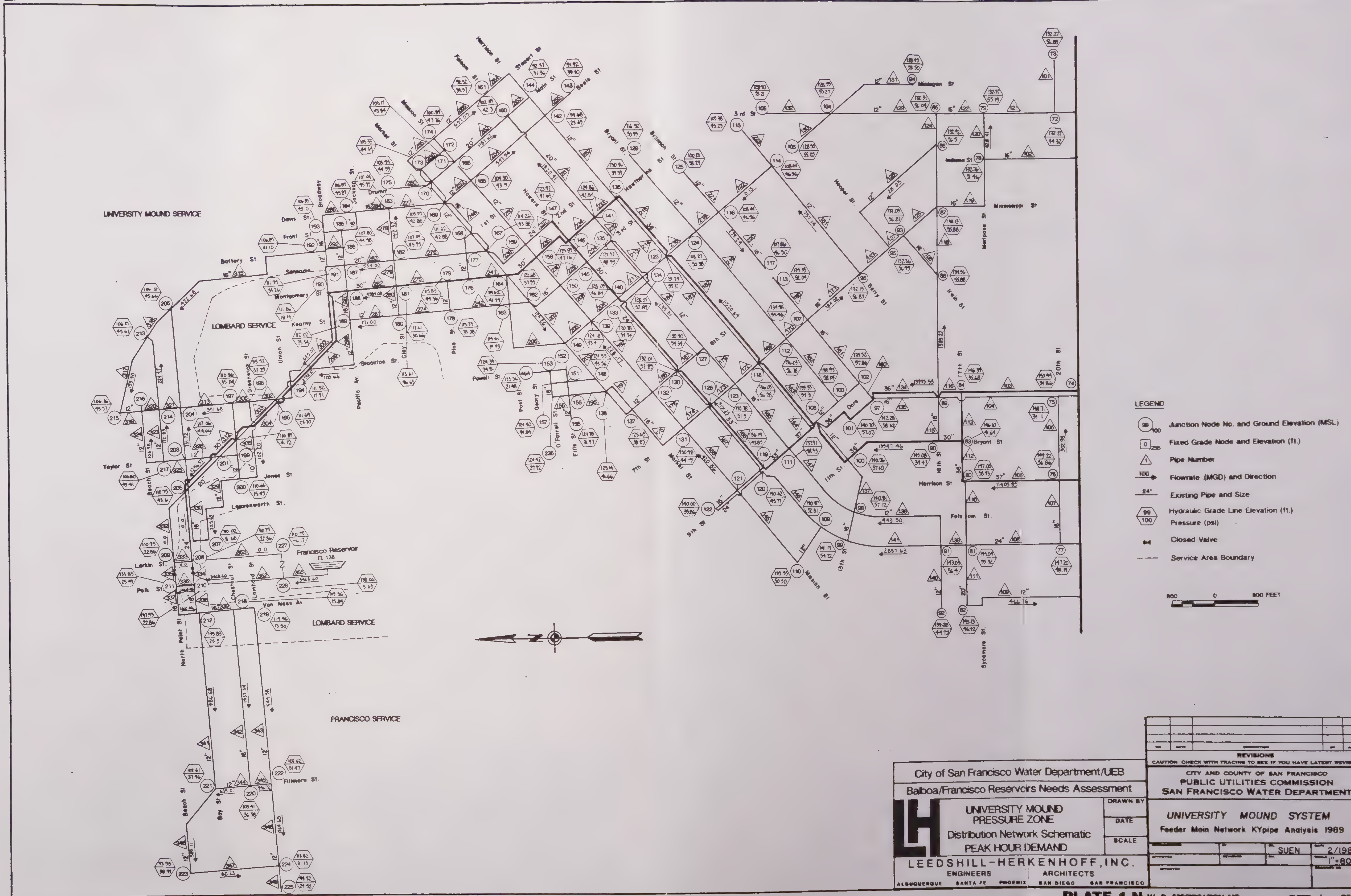


City of San Francisco Water Department/UEB

Balboa/Francisco Reservoirs Needs Assessment

UNIVERSITY MOUND PRESSURE ZONE

Distribution Network Schematic

PEAK HOUR DEMAND

DRAWN BY

DATE

SCALE

LEEDSHILL-HERKENHOFF, INC.

ENGINEERS ARCHITECTS

ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

REVISIONS

CAUTION: CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

CITY AND COUNTY OF SAN FRANCISCO

PUBLIC UTILITIES COMMISSION

SAN FRANCISCO WATER DEPARTMENT

UNIVERSITY MOUND SYSTEM

Feeder Main Network KYpipe Analysis 1989

SUEN 2/1989 1"=800'

PLATE 1-N W. D. SPECIFICATION NO. SHEET 1 OF 2

City of San Francisco Water Department/UEB

Balboa/Francisco Reservoirs Needs Assessment

UNIVERSITY MOUND PRESSURE ZONE
Distribution Network Schematic
PEAK HOUR DEMAND

DRAWN BY | DATE | SCALE

LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

REVISIONS

CAUTION: CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
SAN FRANCISCO WATER DEPARTMENT

UNIVERSITY MOUND SYSTEM

Feeder Main Network KYpipe Analysis 1989

SUEN | 2/1989 | 1"=800'

PLATE 1-S W. D. SPECIFICATION NO. SHEET 2 OF 2


PRESIDIO
GOLDEN GATE PARK
LAKE ST.
CALIFORNIA ST.
GEARY BLVD.
BALBOA ST.
CABRILLO ST.
FULTON ST.
ANZA ST.
LINCOLN WAY
IRVING ST.
JUDAH ST.
KIRKHAM ST
MORAGA ST.
HUGO
FREDERICK
CLAY ST.
PINE ST.
BUSH ST.
POST ST.
EDDY ST.
39 TH. AVE.
34 TH. AVE.
28 TH. AVE.
20 TH. AVE.
23 RD. AVE
18 TH. AVE.
15TH. AVE.
FUNSTON AVE.
9 TH. AVE.
4 TH. AVE.
3 RD. AVE
ARGUELLO
COMMONWEALTH AVE.
DIVISADERO ST.
PRESIDIO AVE.
CENTRAL AVE
SHRADER ST.
STANYAN ST.
COLE ST.
ARGUELLO BLVD.
10TH AVE.
19 TH. AVE.
6 TH. AVE.
N
LEGEND
Junction Node No. and Ground Elevation (MSL)
Fixed Grade Node and Elevation (ft.)
Pipe Number
Flowrate (MGD) and Direction
Existing Pipe and Size
Pressure (psi) Hydraulic Grade Line Elevation (ft.)
Closed Valve
Service Area Boundary
800 0 800 FEET
City of San Francisco Water Department/UEB
Balboa/Francisco Reservoirs Needs Assessment
SUNSET PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND
DRAWN BY
DATE
SCALE
LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

PLATE 2-NW


GREEN ST.
STEINER ST.
FILLMORE ST.
FRANKLIN ST.
HYDE ST.
SUTRO SERVICE
PRIEST ST.
POWELL ST.
STOCKTON ST.
TAYLOR ST.
JONES ST.
CLAY
CALIFORNIA ST.
PINE ST.
BUSH ST.
CLAY ST.
SACRAMENTO ST.
PIERCE ST.
POST ST.
O' FARRELL ST.
MYRTLE ST.
BUCHANAN
GOUGH ST.
LARKIN ST
LEAVENWORTH ST.
SCOTT ST.
MC ALLISTER ST.
COLLEGE HILL SERVICE
GROVE ST.
LAGUNA ST.
OAK ST.
HAIGHT ST.
DUBOCE AVE.
NOE ST.
POND ST.
SANCHEZ ST.
CHURCH ST.
DORLAND ST.
DOLORES ST.
20 TH. ST.
19 TH. ST.
21 ST. ST.
21 ST. STREET
22 ND. STREET
POTRERO HTS. RES.
MARIPOSA ST.
POTRERO ST.
VERMONT ST.
RHODE ISLAND ST.
WISCONSIN ST.
SAN BRUNO AVE.
DEHARO ST.
17 TH ST.
N
LEGEND
Junction Node No. and Ground Elevation (MSL)
Fixed Grade Node and Elevation (ft.)
Pipe Number
Flowrate (MGD) and Direction
Existing Pipe and Size
Pressure (psi)
Hydraulic Grade Line Elevation (ft.)
Closed Valve
Service Area Boundary
800 0 800 FEET
City of San Francisco Water Department/UEB
Balboa/Francisco Reservoirs Needs Assessment
SUNSET PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND
DRAWN BY
DATE
SCALE
LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

PLATE 2-NE

N

LEGEND

- Junction Node No. and Ground Elevation (MSL)
- Fixed Grade Node and Elevation (ft.)
- Pipe Number
- Flowrate (MGD) and Direction
- Existing Pipe and Size
- Pressure (psi) / Hydraulic Grade Line Elevation (ft.)
- Closed Valve
- Service Area Boundary

800 0 800 FEET

City of San Francisco Water Department/UEB

Balboa/Francisco Reservoirs Needs Assessment

SUNSET PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND

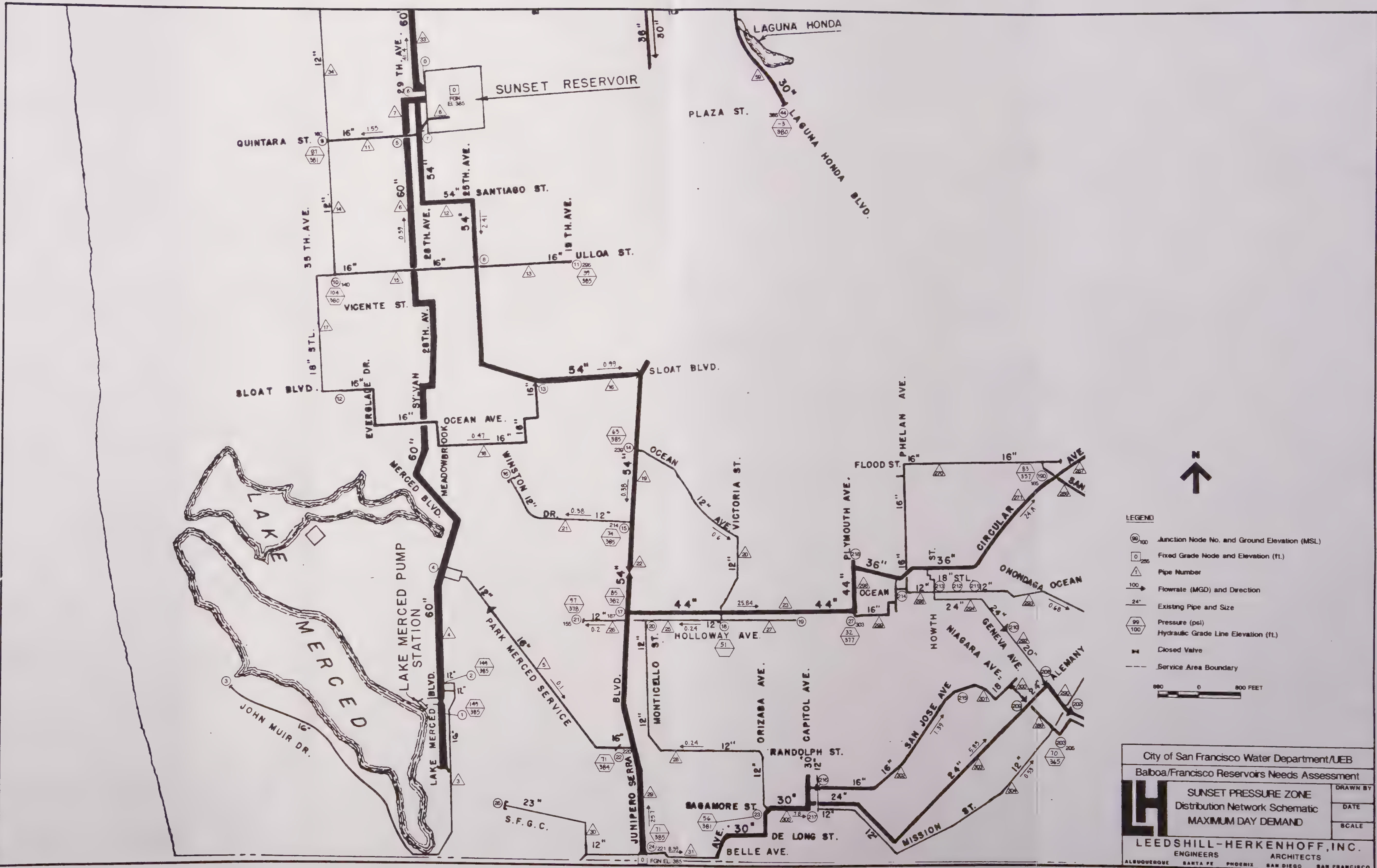
DRAWN BY

DATE

SCALE

LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

PLATE 2-NE



SUNSET RESERVOIR
FGN EL 385
LAGUNA HONDA
LAGUNA HONDA BLVD.
PLAZA ST.
QUINTARA ST.
SANTIAGO ST.
ULLOA ST.
VICENTE ST.
SLOAT BLVD.
OCEAN AVE.
35 TH. AVE.
29 TH. AVE.
28 TH. AVE.
25TH. AVE.
20TH. AV.
19 TH. AVE.
SYLVAN
EVERGLADE DR.
MEADOWBROOK
WINSTON DR.
MERCED BLVD.
LAKE MERCED
LAKE MERCED PUMP STATION
LAKE MERCED BLVD.
JOHN MUIR DR.
PARK MERCED SERVICE
JUNIPERO SERRA BLVD.
S.F.G.C.
OCEAN AVE
VICTORIA ST.
HOLLOWAY AVE.
MONTICELLO ST.
ORIZABA AVE.
CAPITOL AVE.
RANDOLPH ST.
SAGAMORE ST.
DE LONG ST.
BELLE AVE.
PLYMOUTH AVE.
PHELAN AVE.
FLOOD ST.
CIRCULAR AVE
SAN
ONONDAGA
OCEAN
HOWTH ST.
NIAGARA AVE.
GENEVA AVE.
ALEMANY
SAN JOSE AVE
MISSION ST.
N
LEGEND
Junction Node No. and Ground Elevation (MSL)
Fixed Grade Node and Elevation (ft.)
Pipe Number
Flowrate (MGD) and Direction
Existing Pipe and Size
Pressure (psi)
Hydraulic Grade Line Elevation (ft.)
Closed Valve
Service Area Boundary
800 0 800 FEET
City of San Francisco Water Department/UEB
Balboa/Francisco Reservoirs Needs Assessment
SUNSET PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND
DRAWN BY
DATE
SCALE
LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

PLATE 2-SW

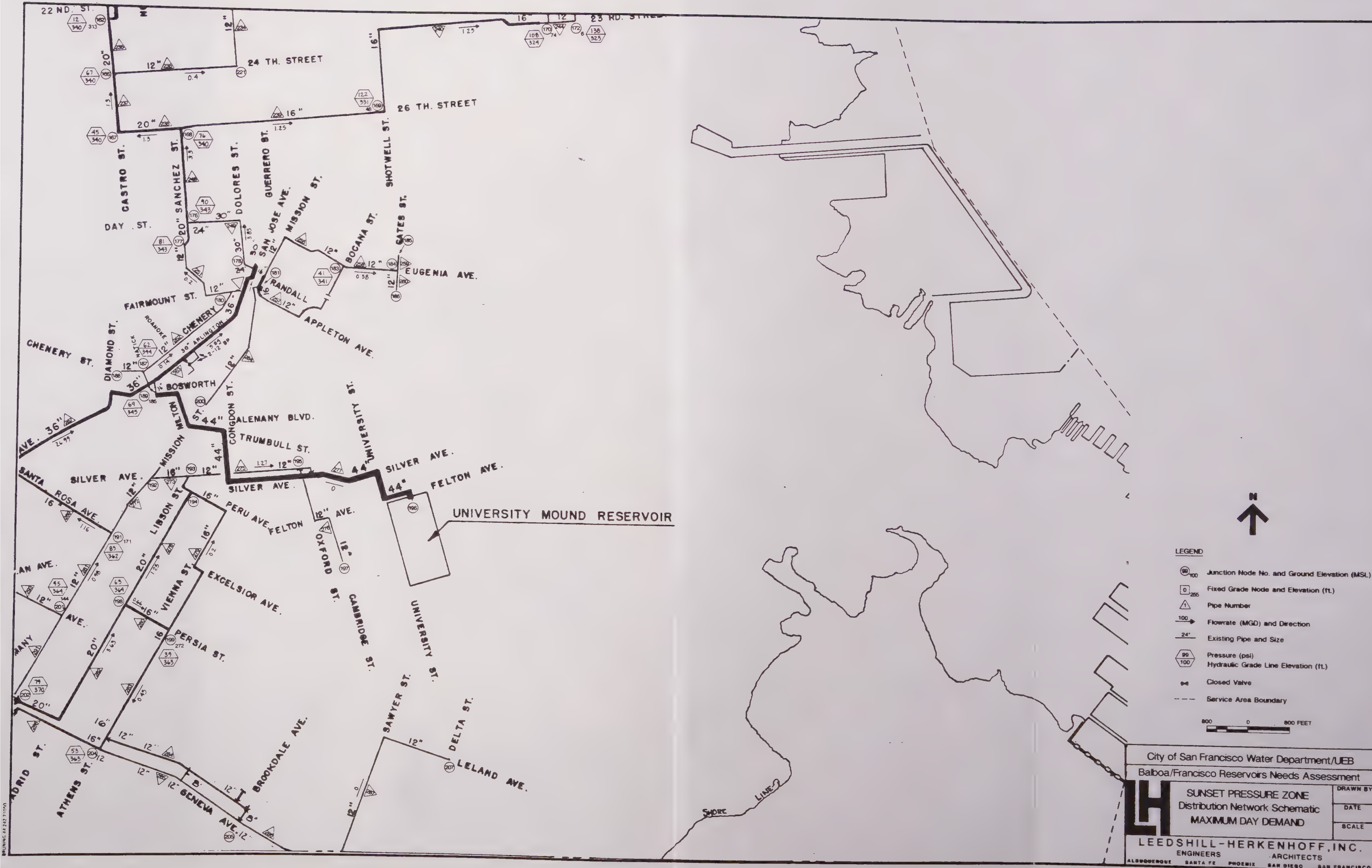

22 ND. ST.
23 RD. STREET
24 TH. STREET
26 TH. STREET
CASTRO ST.
SANCHEZ ST.
DOLORES ST.
GUERRERO ST.
SHOTWELL ST.
DAY ST.
SAN JOSE AVE.
MISSION ST.
BOCANA ST.
GATES ST.
EUGENIA AVE.
RANDALL
APPLETON AVE.
FAIRMOUNT ST.
CHENERY
CHENERY ST.
DIAMOND ST.
ARLINGTON
BOSWORTH
ALEMANY BLVD.
CONGDON ST.
TRUMBULL ST.
UNIVERSITY ST.
SILVER AVE.
FELTON AVE.
MISSION ST.
MILTON ST.
SANTA ROSA AVE.
LISBON ST.
PERU AVE.
FELTON AVE.
OXFORD ST.
CAMBRIDGE ST.
UNIVERSITY ST.
UNIVERSITY MOUND RESERVOIR
EXCELSIOR AVE.
VIENNA ST.
PERSIA ST.
ATHENS ST.
MADRID ST.
GENEVA AVE.
BROOKDALE AVE.
SAWYER ST.
DELTA ST.
LELAND AVE.
SHORE LINE
N
LEGEND
Junction Node No. and Ground Elevation (MSL)
Fixed Grade Node and Elevation (ft.)
Pipe Number
Flowrate (MGD) and Direction
Existing Pipe and Size
Pressure (psi)
Hydraulic Grade Line Elevation (ft.)
Closed Valve
Service Area Boundary
800 0 800 FEET
City of San Francisco Water Department/UEB
Balboa/Francisco Reservoirs Needs Assessment
SUNSET PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND
DRAWN BY
DATE
SCALE
LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

PLATE 2-SE

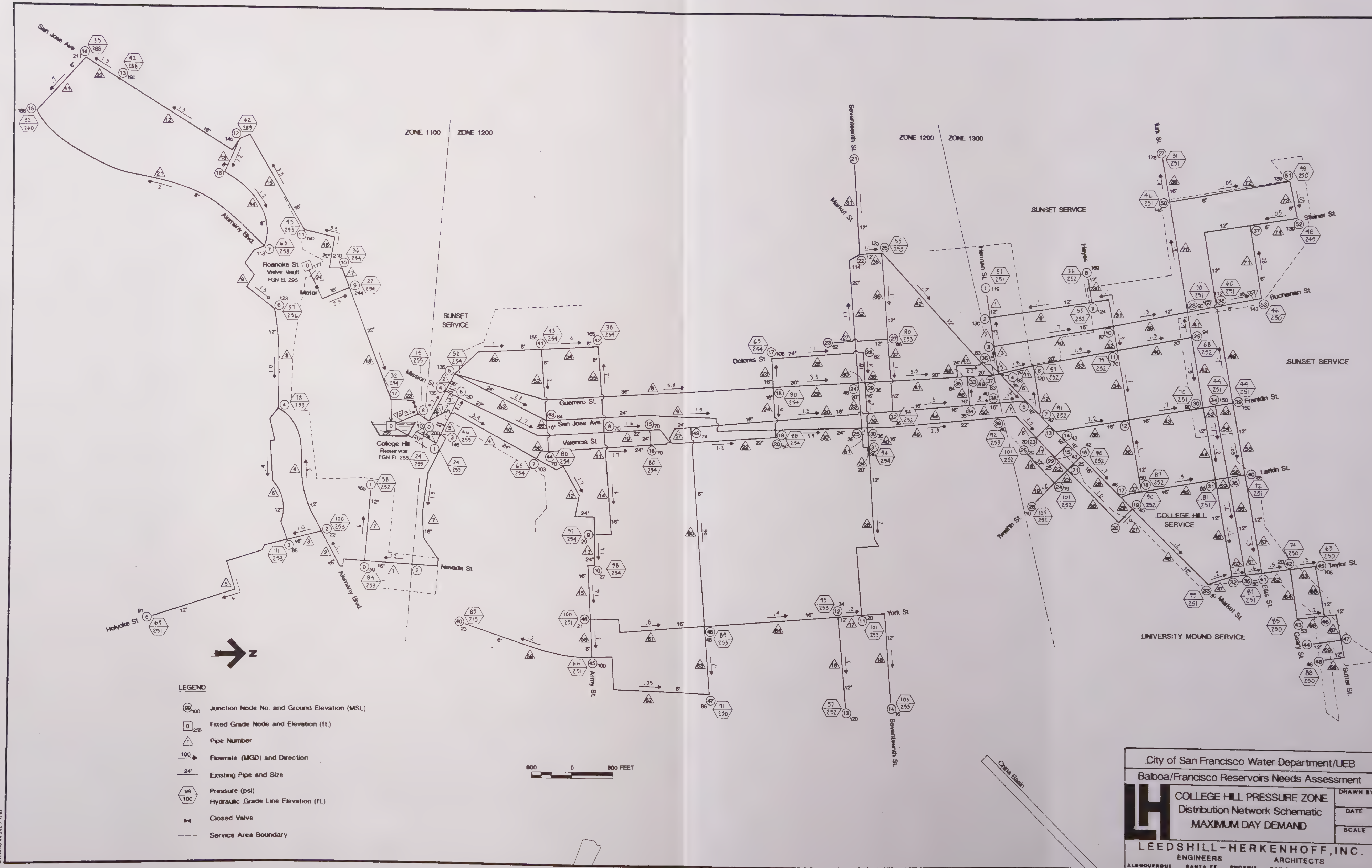
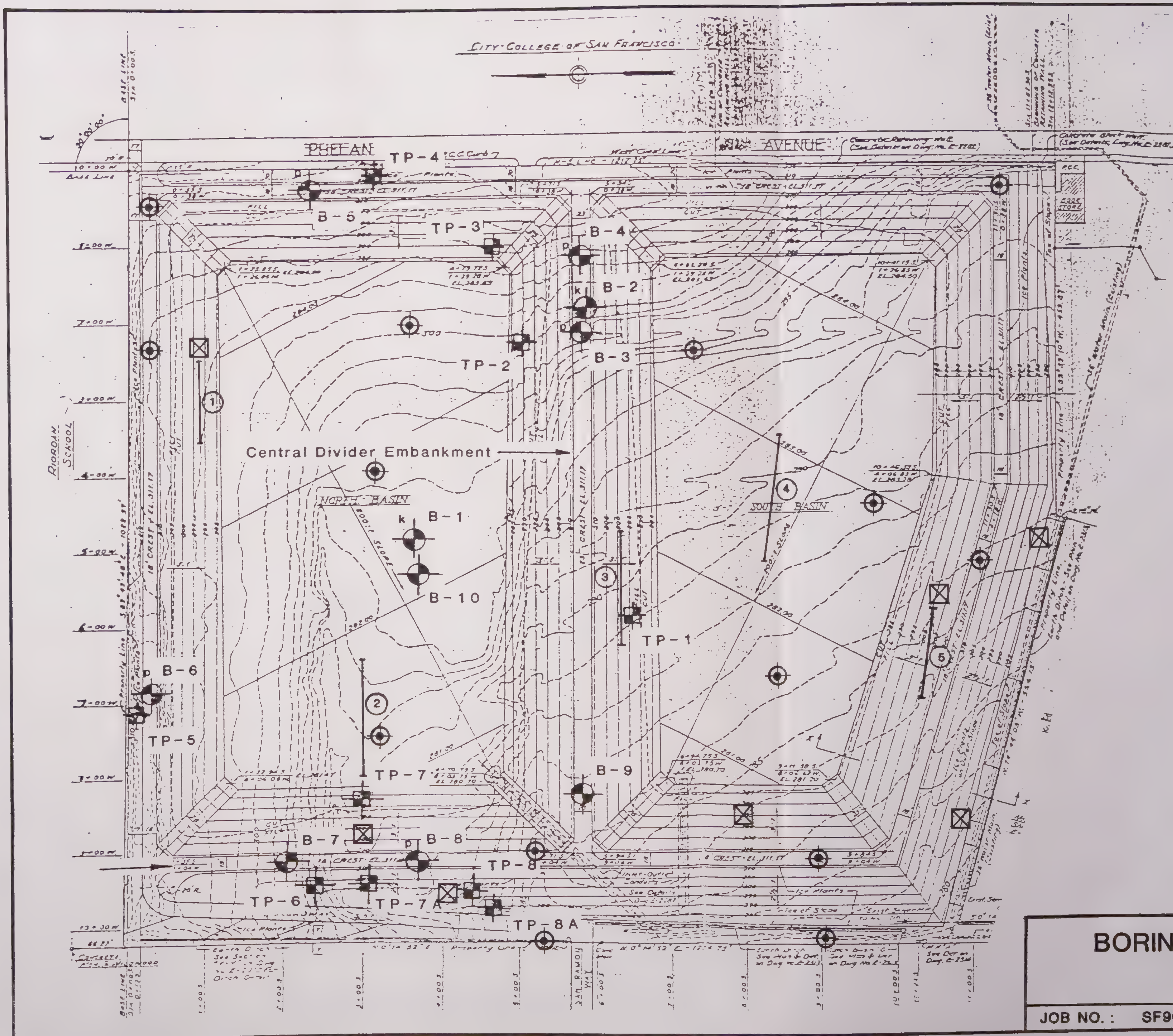

ZONE 1100
ZONE 1200
ZONE 1200
ZONE 1300
SUNSET SERVICE
COLLEGE HILL SERVICE
UNIVERSITY MOUND SERVICE
San Jose Ave.
Alemany Blvd.
Roanoke St. Valve Vault FGN El. 295
Meter
Mission St.
College Hill Reservoir FGN El. 255
Guerrero St.
San Jose Ave.
Valencia St.
Dolores St.
Seventeenth St.
Market St.
Herman St.
Hayes
Turk St.
Steiner St.
Buchanan St.
Franklin St.
Larkin St.
Twelfth St.
Taylor St.
Ellis St.
Geary St.
Sutter St.
York St.
Army St.
Nevada St.
Holyoke St.
China Basin
LEGEND
Junction Node No. and Ground Elevation (MSL)
Fixed Grade Node and Elevation (ft.)
Pipe Number
Flowrate (MGD) and Direction
Existing Pipe and Size
Pressure (psi)
Hydraulic Grade Line Elevation (ft.)
Closed Valve
Service Area Boundary
800 0 800 FEET
City of San Francisco Water Department/UEB
Balboa/Francisco Reservoirs Needs Assessment
COLLEGE HILL PRESSURE ZONE
Distribution Network Schematic
MAXIMUM DAY DEMAND
DRAWN BY
DATE
SCALE
LEEDSHILL-HERKENHOFF, INC.
ENGINEERS ARCHITECTS
ALBUQUERQUE SANTA FE PHOENIX SAN DIEGO SAN FRANCISCO

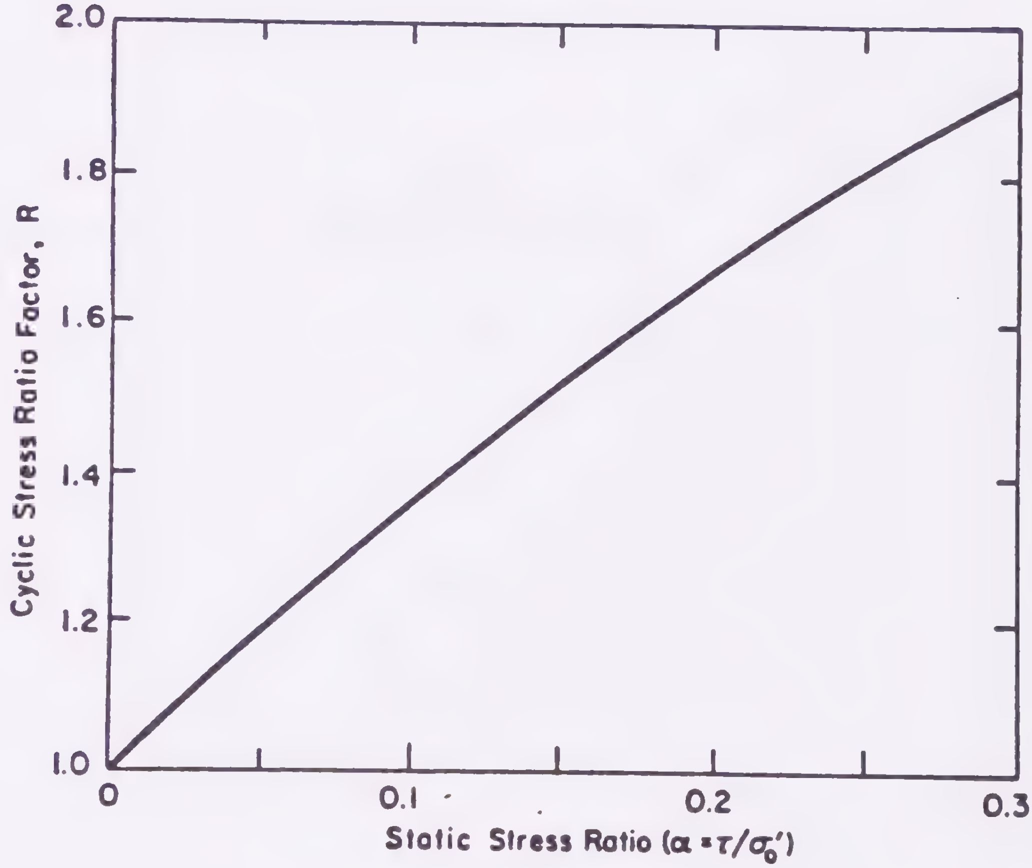
PLATE 3



BORING LOCATION MAP

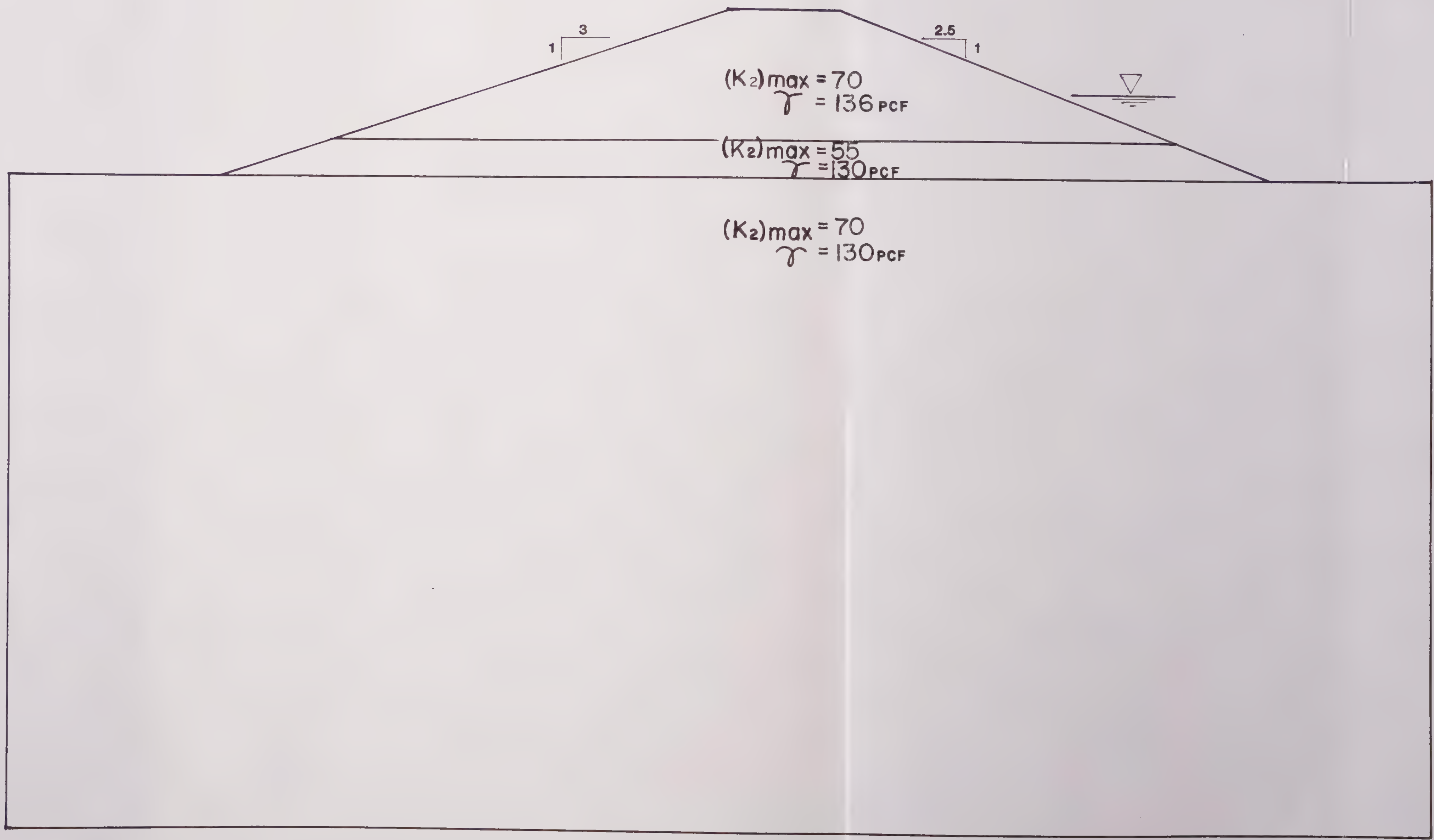
AGS, Inc.
CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS

JOB NO.: SF90506	DATE: 12/89	PLATE 4

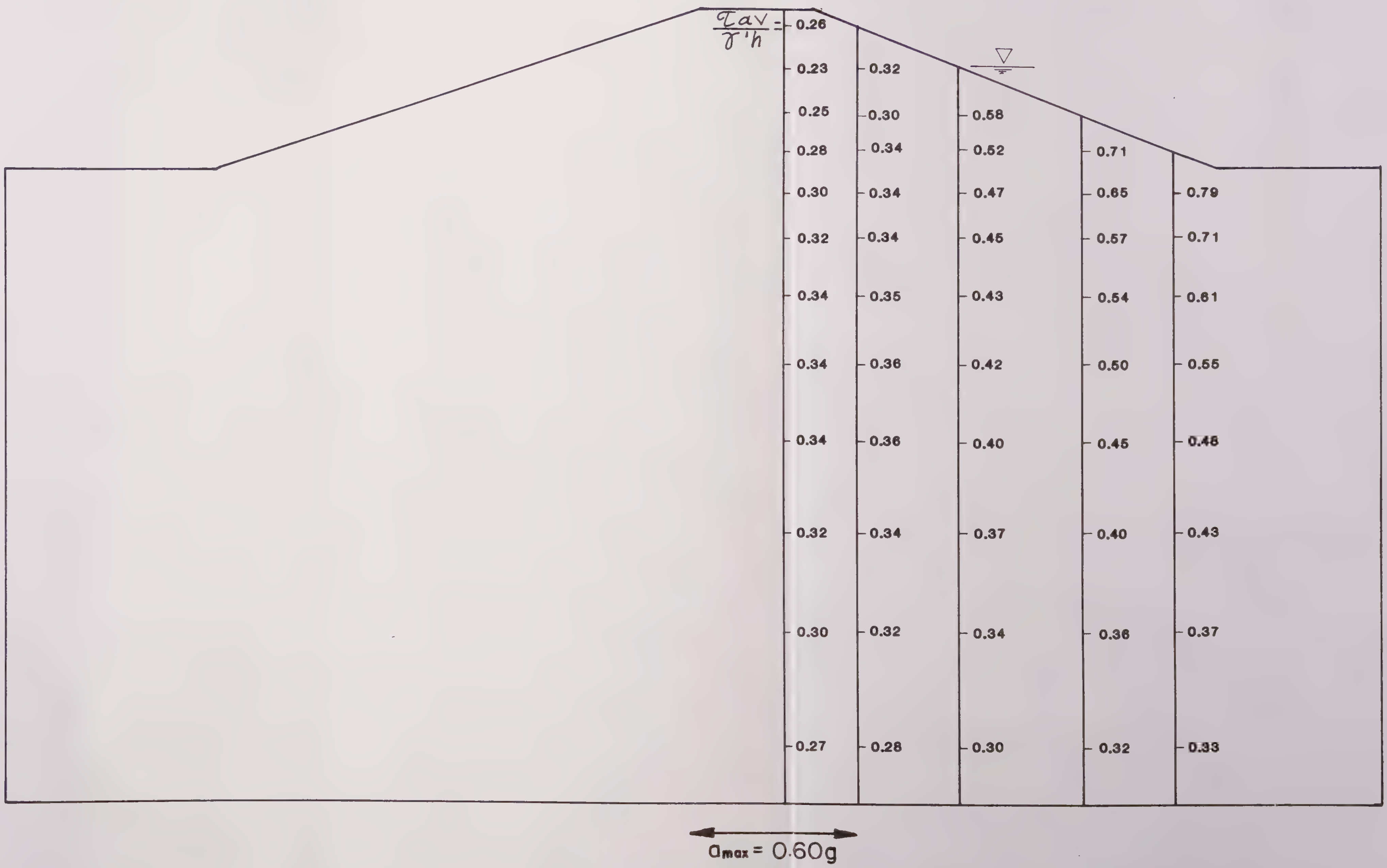


ADAPTED FROM SEED (1981)

RELATIONSHIP BETWEEN STATIC STRESS RATIO AND CYCLIC STRENGTH OF SANDS		AGS, Inc. CONSULTING GEOTECHNICAL STRUCTURAL, AND CIVIL ENGINEERS
JOB NO. : SF90506	DATE : 12/89	PLATE 5



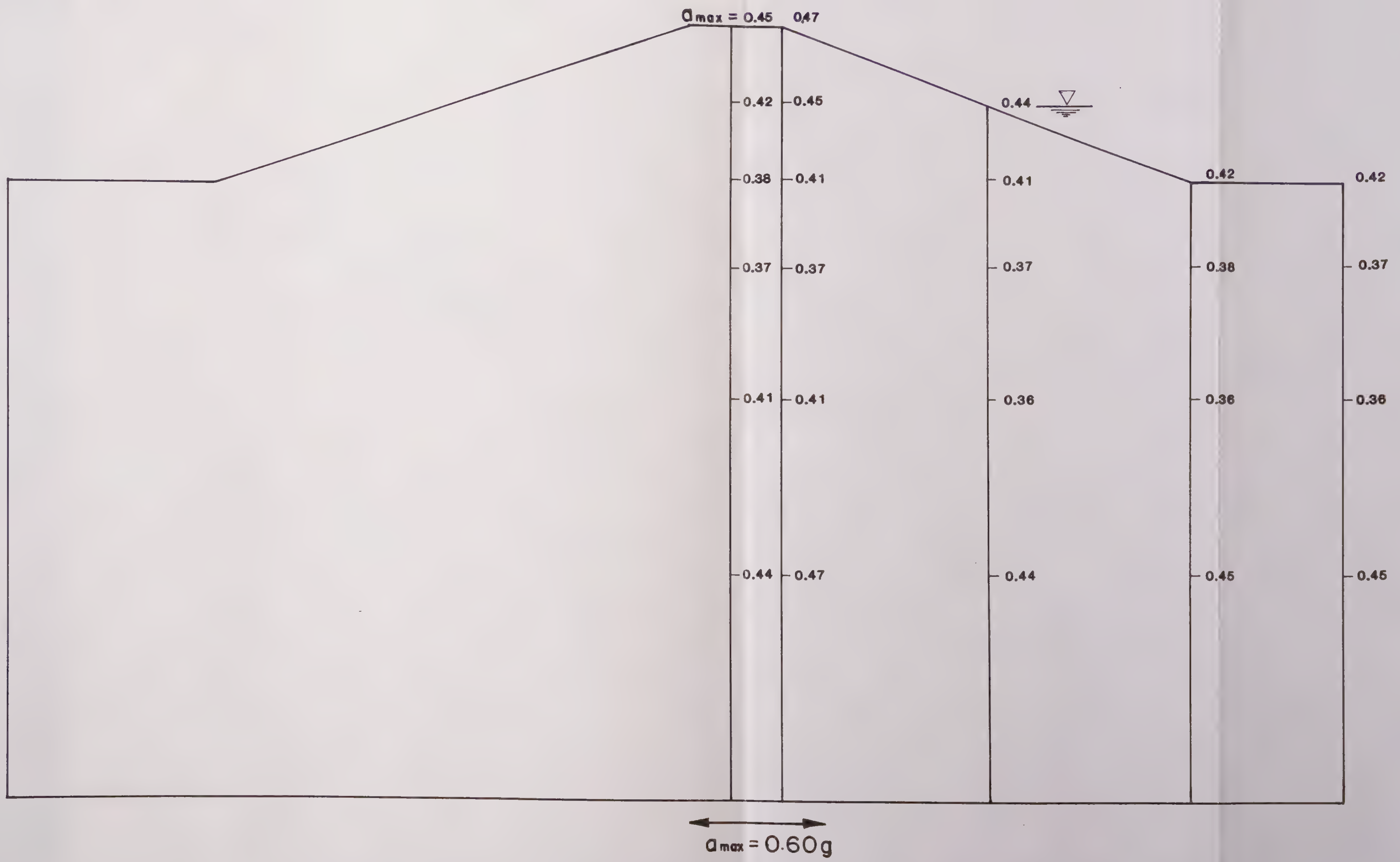
GEOTECHNICAL PROFILE		AGS, Inc. CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS
JOB NO. : SF90506	DATE : 12/89	PLATE 6



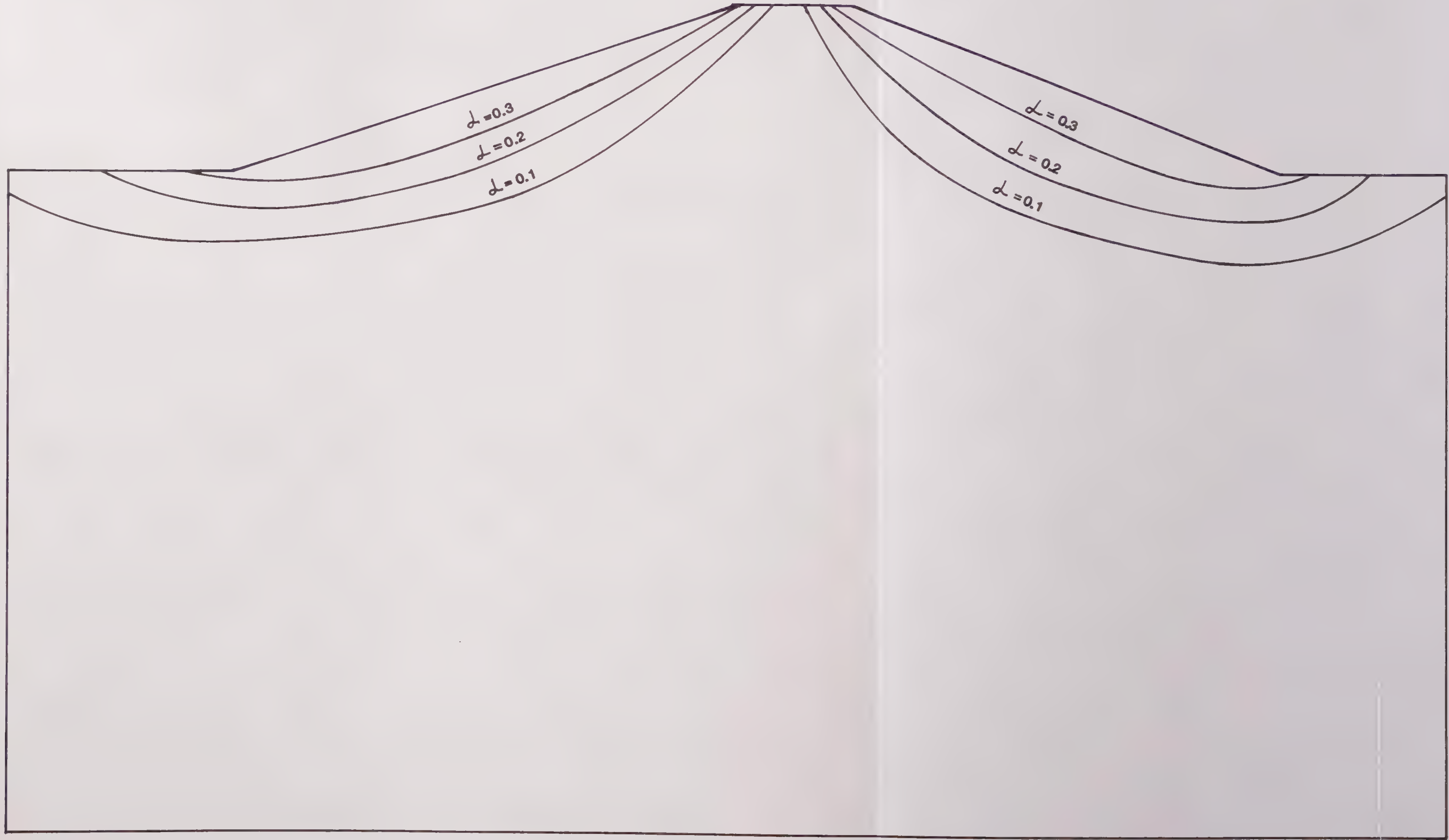
CYCLIC STRESS RATIOS

AGS, Inc.
CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS

JOB NO. : SF90506	DATE : 12/89	PLATE 7



MAXIMUM ACCELERATIONS		AGS, Inc. CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS
JOB NO. : SF90506	DATE : 12/89	PLATE 8



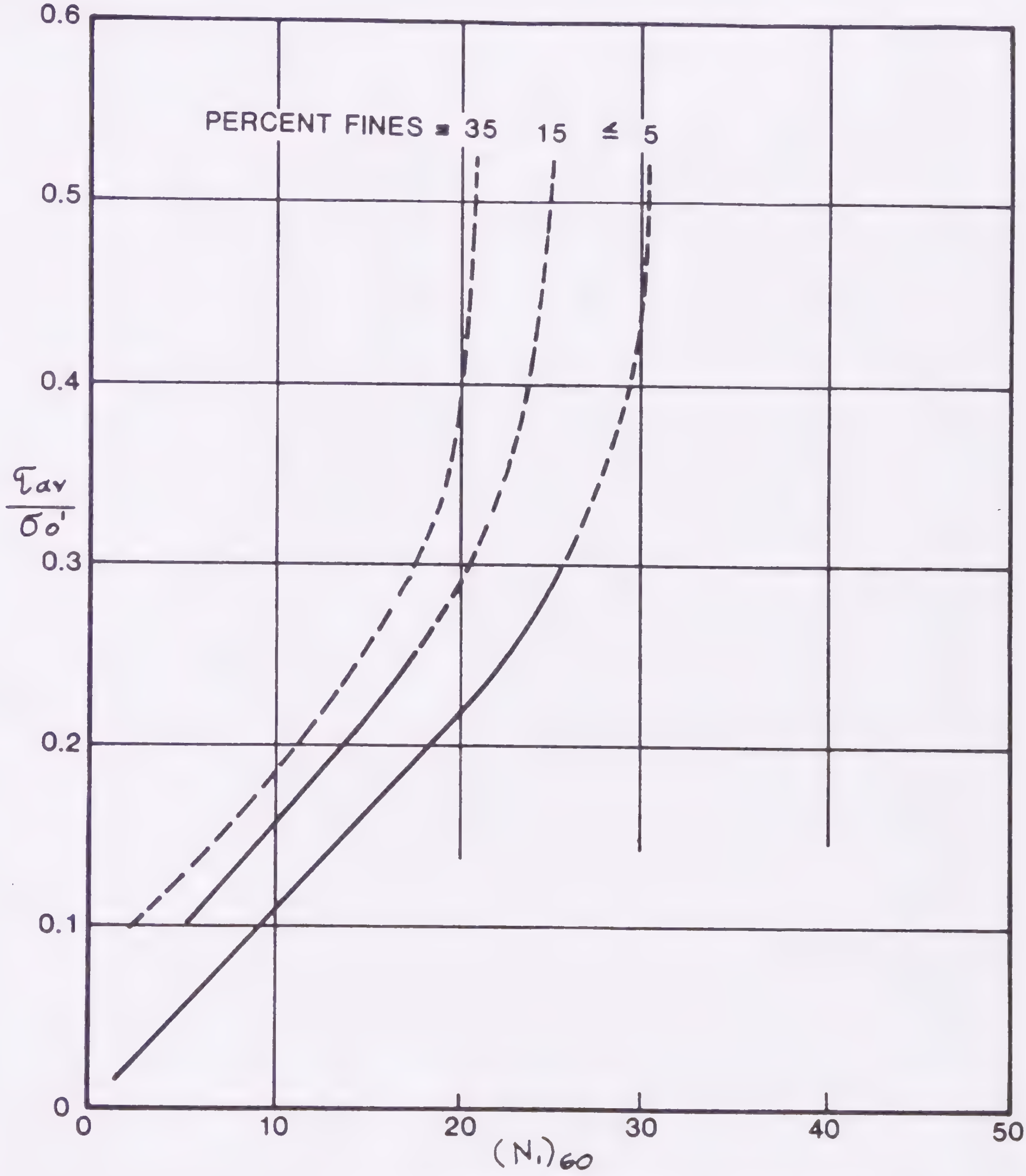
LEGEND:

$$\alpha = \frac{\tau}{\gamma' \cdot h}$$

STATIC SHEAR STRESSES

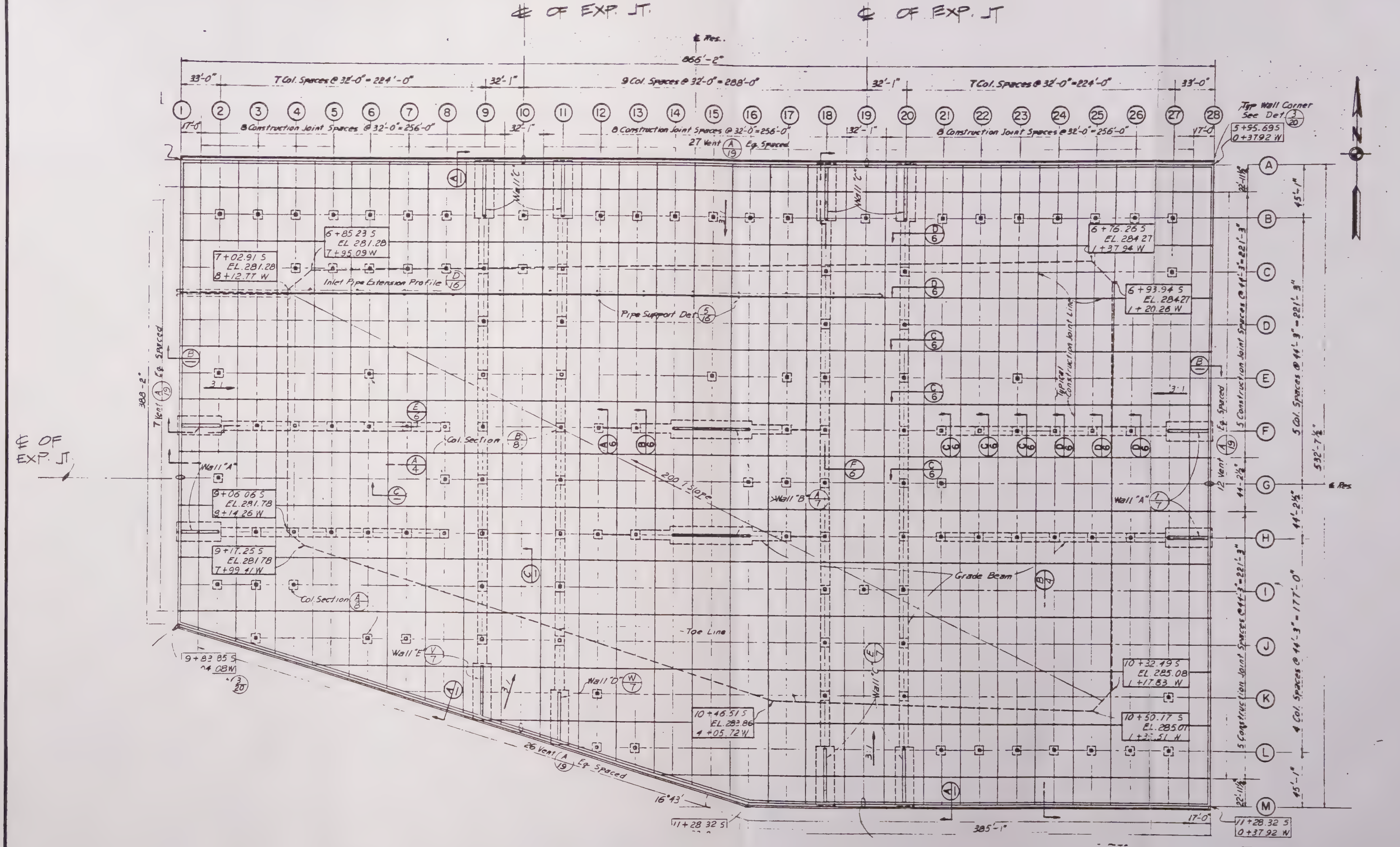
AGS, Inc.
CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS

JOB NO. : SF90506 | DATE : 12/89 | PLATE 9



ADAPTED FROM SEED AND OTHERS (1984)

FIELD LIQUEFACTION DATA FOR SANDY SOIL		AGS, Inc. CONSULTING GEOTECHNICAL STRUCTURAL, AND CIVIL ENGINEERS
JOB NO. : SF90506	DATE : 12/89	PLATE 10



PLAN

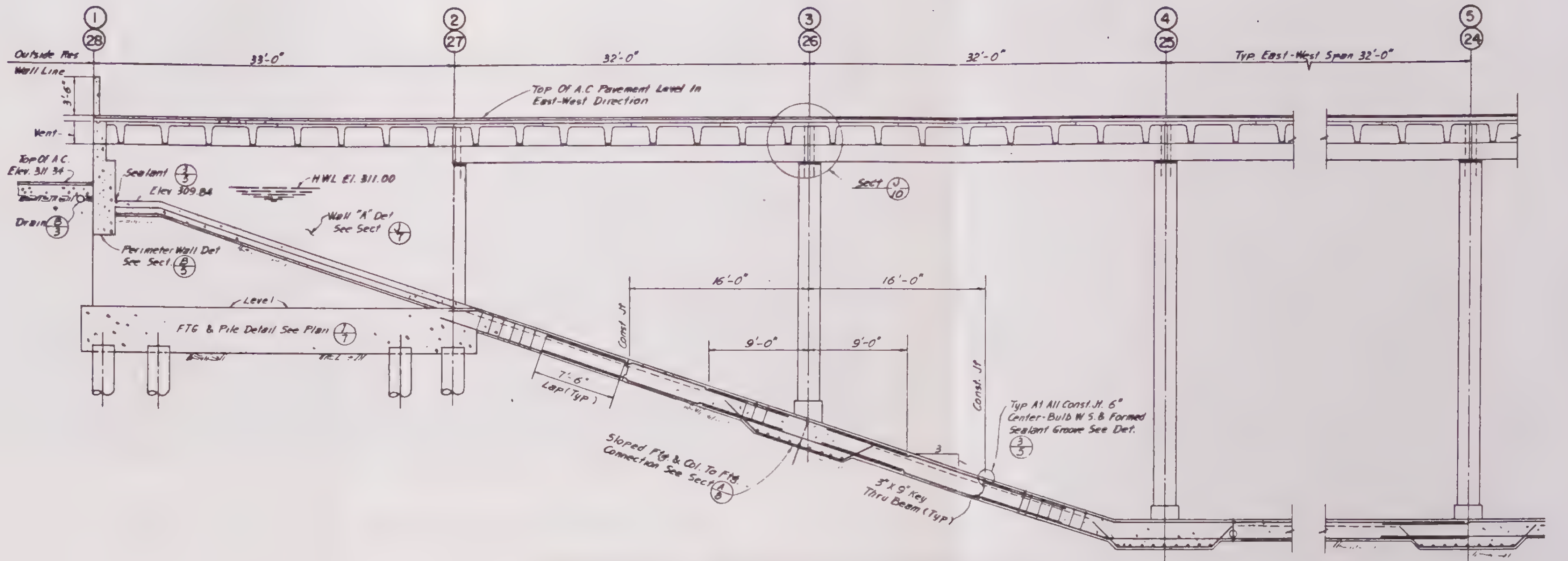
N.T.S.

PLAN LAYOUT

BALBOA RESERVOIR

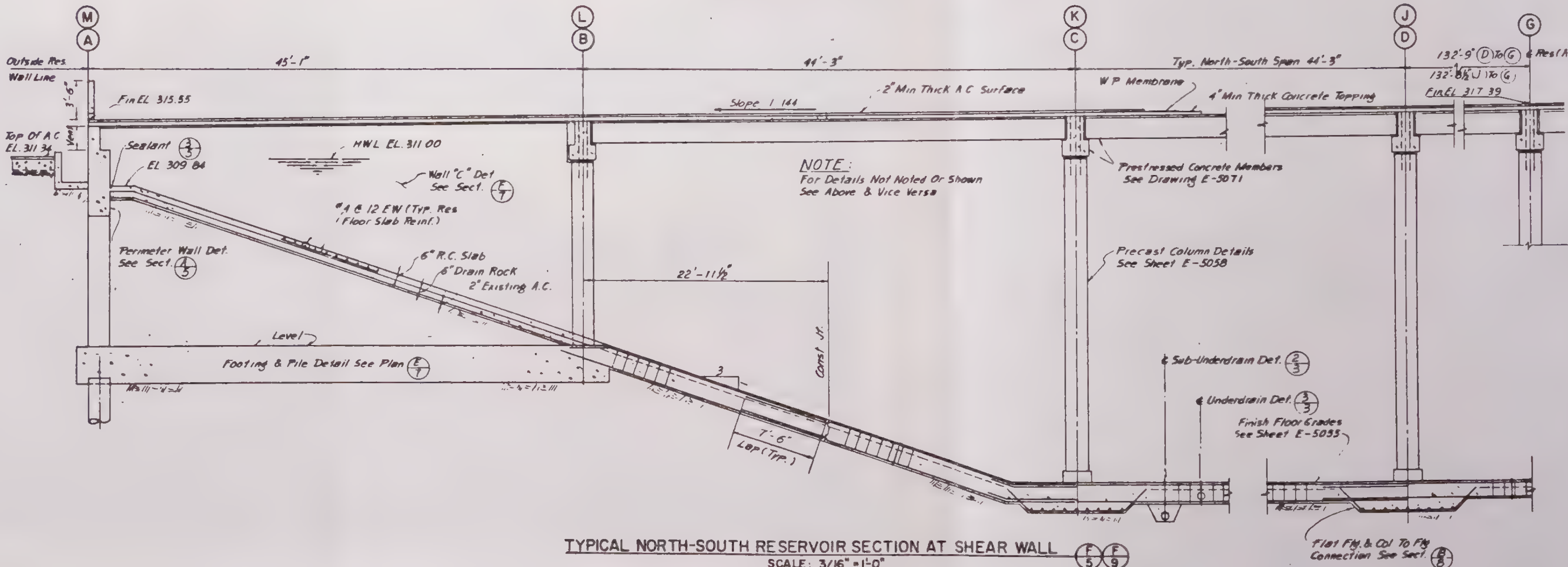
AGS, Inc.
CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS

JOB NO.:	SF90506	DATE:	12/89	PLATE	11



TYPICAL EAST-WEST RESERVOIR SECTION AT SHEAR WALL

SCALE: 3/16"=1' 0"



TYPICAL NORTH-SOUTH RESERVOIR SECTION AT SHEAR WALL

SCALE: 3/16"=1'-0"

SECTIONS

N.T.S.

GENERAL SECTIONS BALBOA RESERVOIR		AGS, Inc. CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS
JOB NO.: SF90506	DATE: 12/89	PLATE 12

POST CONDITION

ROOF DAYLIGTING CONDITION

ROOF CONDITION (LOOKING EAST)

POST FOOTING CONDITION

BOTTOM LINING CONDITION

ROOF CONDITION (LOOKING WEST)

EXISTING STRUCTURAL CONDITIONS
FRANCISCO RESERVOIR

AGS, Inc.
CONSULTING GEOTECHNICAL, STRUCTURAL, AND CIVIL ENGINEERS

JOB NO. : SF90506	DATE : 12/89	PLATE 13

APPENDIX A

KYPIPES DISTRIBUTION MODEL OUTPUT

1. University Mound/Francisco Peak Hour
2. Sunset Maximum Day
3. College Hill Maximum Day

Water distribution schematics showing model results

UNIVERSITY MOUND - PEAK HOUR DEMAND
FRANCISCO RESERVOIR TIED IN AT 138 FEET

FLOWRATE IS EXPRESSED IN GPM AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

PIPE NO.	NODE NOS.		LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1	0	1	900.0	12.0	85.0	.00	172.00
2	1	2	2600.0	12.0	63.0	.00	
3	2	3	1200.0	12.0	86.0	.00	
4	2	4	1800.0	12.0	130.0	.00	
5	4	5	2800.0	12.0	110.0	.00	
6	5	6	2000.0	18.0	110.0	.00	
7	6	7	1100.0	16.0	99.0	.00	
8	7	11	2700.0	16.0	85.0	.00	
9	0	8	1200.0	24.0	110.0	.00	172.00
10	8	9	900.0	12.0	65.0	.00	
11	9	10	3850.0	12.0	84.0	.00	
12	10	11	600.0	16.0	79.0	.00	
13	8	16	3800.0	24.0	110.0	.00	
14	16	17	1400.0	12.0	57.0	.00	
15	16	17	1400.0	24.0	110.0	.00	
16	11	17	3100.0	16.0	79.0	.00	
17	17	18	900.0	20.0	110.0	.00	
18	18	19	5000.0	16.0	72 0	.00	
19	0	12	2300.0	44.0	110.0	.00	172.00
20	0	12	2300.0	48.0	110.0	.00	172.00
21	12	13	600.0	16.0	54.0	.00	
22	8	13	1800.0	12.0	65.0	.00	
23	13	14	1200.0	16.0	54.0	.00	
24	14	15	1000.0	12.0	81.0	.00	
25	15	16	2000.0	12.0	57.0	.00	
26	12	20	700.0	44.0	110.0	.00	
27	12	20	700.0	48.0	110.0	.00	
28	20	21	1100.0	48.0	110.0	.00	
29	20	21	1100.0	44.0	110.0	.00	
30	21	47	3100.0	44.0	110.0	.00	
31	21	22	3800.0	48.0	110.0	.00	
32	22	23	400.0	16.0	77.0	.00	
33	23	24	1500.0	12.0	76.0	.00	
34	23	25	3200.0	16.0	78.0	.00	
35	25	26	1350.0	16.0	78.0	.00	
36	26	27	800.0	16.0	114.0	.00	
37	27	18	600.0	20.0	110.0	.00	
38	27	28	300.0	16.0	70.0	.00	
39	26	28	460.0	16.0	78.0	.00	
40	28	29	300.0	16.0	70.0	.00	
41	29	30	1000.0	12.0	75.0	.00	
42	25	31	1550.0	12.0	86.0	.00	
43	26	32	2330.0	16.0	114.0	.00	
44	32	31	1020.0	12.0	114.0	.00	
45	31	33	2400.0	12.0	86.0	.00	
46	47	48	1500.0	24.0	110.0	.00	
47	47	58	2000.0	37.0	110.0	.00	
48	22	49	2800.0	48.0	110.0	.00	
49	22	50	2550.0	12.0	63.0	.00	
50	48	49	1350.0	16.0	72.0	.00	
51	49	50	900.0	16.0	110.0	.00	
52	50	54	3250.0	16.0	67.0	.00	
53	50	51	1900.0	12.0	52.0	.00	
54	51	52	1000.0	12.0	66.0	.00	
55	52	53	800.0	12.0	73.0	.00	
56	52	53	700.0	12.0	66.0	.00	
57	33	34	2200.0	12.0	66.0	.00	

58	34	35	600.0	16.0	70.0	.00
59	35	29	1800.0	16.0	70.0	.00
60	34	37	480.0	16.0	98.0	.00
61	35	36	260.0	12.0	80.0	.00
62	36	38	900.0	12.0	80.0	.00
63	36	37	600.0	12.0	98.0	.00
64	37	39	670.0	16.0	98.0	.00
65	37	40	1000.0	12.0	114.0	.00
66	39	40	800.0	12.0	114.0	.00
67	40	41	500.0	12.0	114.0	.00
68	38	42	1900.0	12.0	98.0	.00
69	39	42	1300.0	16.0	98.0	.00
70	42	43	650.0	16.0	98.0	.00
71	43	44	1050.0	16.0	112.0	.00
72	43	45	3200.0	16.0	130.0	.00
73	34	46	3200.0	16.0	77.0	.00
74	51	54	1400.0	12.0	51.0	.00
75	54	55	1400.0	12.0	51.0	.00
76	55	56	1000.0	12.0	48.0	.00
77	55	57	1500.0	12.0	76.0	.00
78	55	71	2800.0	12.0	48.0	.00
79	54	68	2340.0	16.0	94.0	.00
80	48	59	750.0	24.0	110.0	.00
81	58	59	250.0	16.0	55.0	.00
82	59	60	500.0	16.0	55.0	.00
83	58	62	1950.0	16.0	55.0	.00
84	58	61	600.0	37.0	110.0	.00
85	49	67	1100.0	48.0	110.0	.00
86	61	67	1400.0	36.0	110.0	.00
87	50	62	1500.0	12.0	54.0	.00
88	59	63	1100.0	24.0	110.0	.00
89	63	64	2100.0	12.0	47.0	.00
90	64	65	1100.0	12.0	92.0	.00
91	64	69	1800.0	12.0	97.0	.00
92	64	66	500.0	12.0	47.0	.00
93	61	63	900.0	37.0	110.0	.00
94	63	77	3500.0	24.0	110.0	.00
95	63	76	2300.0	37.0	110.0	.00
96	62	75	2800.0	16.0	52.0	.00
97	67	74	2300.0	44.0	110.0	.00
98	68	70	700.0	16.0	67.0	.00
99	70	71	800.0	12.0	83.0	.00
100	71	72	900.0	12.0	52.0	.00
101	72	73	1100.0	12.0	50.0	.00
102	70	78	2300.0	16.0	67.0	.00
103	74	84	2400.0	44.0	110.0	.00
104	75	89	2300.0	16.0	52.0	.00
105	75	76	1600.0	16.0	57.0	.00
106	76	80	1700.0	37.0	110.0	.00
107	76	77	1300.0	16.0	57.0	.00
108	77	81	1700.0	24.0	110.0	.00
109	69	82	3000.0	12.0	105.0	.00
110	80	81	1300.0	20.0	56.0	.00
111	81	82	1300.0	20.0	56.0	.00
112	80	83	800.0	36.0	110.0	.00
113	83	84	800.0	36.0	110.0	.00
114	83	90	450.0	36.0	110.0	.00
115	89	90	800.0	16.0	71.0	.00
116	84	89	450.0	36.0	110.0	.00
117	89	88	2200.0	16.0	70.0	.00
118	88	87	1300.0	16.0	70.0	.00
119	87	78	1800.0	16.0	52.0	.00
120	78	79	850.0	16.0	52.0	.00
121	72	79	1400.0	16.0	49.0	.00
122	79	85	900.0	16.0	49.0	.00
123	87	86	1200.0	16.0	70.0	.00
124	86	85	550.0	16.0	70.0	.00
125	87	93	1000.0	16.0	52.0	.00
126	88	93	1000.0	16.0	54.0	.00
127	93	95	300.0	16.0	52.0	.00
128	95	86	3000.0	12.0	50.0	.00
129	85	104	2100.0	12.0	49.0	.00

130	104	105	850.0	12.0	49.0	.00
131	104	94	2000.0	12.0	82.0	.00
132	104	106	1400.0	12.0	53.0	.00
133	95	96	800.0	16.0	52.0	.00
134	89	97	1300.0	36.0	110.0	.00
135	89	97	1300.0	16.0	52.0	.00
136	90	100	2000.0	36.0	110.0	.00
137	100	98	1300.0	16.0	55.0	.00
138	91	98	2200.0	12.0	95.0	.00
139	81	91	600.0	24.0	110.0	.00
140	91	92	1300.0	12.0	52.0	.00
141	91	99	2250.0	24.0	110.0	.00
142	99	98	600.0	16.0	55.0	.00
143	99	109	750.0	24.0	110.0	.00
144	109	110	600.0	12.0	53.0	.00
145	110	121	1600.0	12.0	44.0	.00
146	109	120	1600.0	24.0	110.0	.00
147	98	111	1900.0	12.0	52.0	.00
148	100	108	700.0	36.0	110.0	.00
149	100	108	1100.0	12.0	49.0	.00
150	97	101	800.0	36.0	110.0	.00
151	101	108	700.0	36.0	110.0	.00
152	108	111	800.0	37.0	110.0	.00
153	111	119	600.0	33.0	110.0	.00
154	120	122	1250.0	24.0	59.0	.00
155	119	121	650.0	16.0	50.0	.00
156	226	155	300.0	16.0	55.0	.00
157	121	122	600.0	16.0	50.0	.00
158	108	103	600.0	12.0	49.0	.00
159	103	102	600.0	12.0	49.0	.00
160	97	102	400.0	16.0	53.0	.00
161	102	107	1500.0	16.0	53.0	.00
162	103	112	1500.0	12.0	52.0	.00
163	108	118	1800.0	36.0	110.0	.00
164	108	118	1500.0	12.0	47.0	.00
165	111	123	1500.0	16.0	52.0	.00
166	119	126	1600.0	33.0	110.0	.00
167	119	126	1600.0	24.0	110.0	.00
168	121	131	1600.0	12.0	44.0	.00
169	112	118	600.0	16.0	52.0	.00
170	112	107	600.0	16.0	52.0	.00
171	107	96	1300.0	16.0	52.0	.00
172	118	123	700.0	16.0	52.0	.00
173	123	126	600.0	16.0	52.0	.00
174	126	131	700.0	16.0	52.0	.00
175	131	137	1500.0	16.0	52.0	.00
176	131	132	900.0	12.0	44.0	.00
177	126	130	900.0	24.0	110.0	.00
178	126	130	900.0	30.0	110.0	.00
179	123	127	900.0	12.0	47.0	.00
180	107	113	800.0	16.0	53.0	.00
181	96	114	2700.0	12.0	49.0	.00
182	118	128	2800.0	36.0	110.0	.00
183	118	128	2800.0	12.0	47.0	.00
184	127	134	1900.0	12.0	47.0	.00
185	130	140	1800.0	30.0	110.0	.00
186	130	133	1700.0	24.0	110.0	.00
187	127	130	600.0	12.0	48.0	.00
188	130	132	700.0	12.0	48.0	.00
189	132	137	600.0	12.0	48.0	.00
190	137	138	600.0	12.0	93.0	.00
191	137	138	600.0	16.0	99.0	.00
192	132	139	1900.0	12.0	44.0	.00
193	138	148	200.0	12.0	93.0	.00
194	148	151	600.0	12.0	98.0	.00
195	138	155	800.0	16.0	55.0	.00
196	151	155	200.0	12.0	49.0	.00
197	155	156	450.0	12.0	49.0	.00
198	151	152	200.0	12.0	49.0	.00
199	152	153	300.0	12.0	50.0	.00
200	153	157	200.0	16.0	55.0	.00
201	157	226	200.0	16.0	55.0	.00

202	153	154	300.0	12.0	50.0	.00
203	148	149	1000.0	12.0	93.0	.00
204	140	139	700.0	12.0	49.0	.00
205	139	149	600.0	12.0	49.0	.00
206	149	163	2000.0	12.0	49.0	.00
207	149	162	900.0	12.0	93.0	.00
208	139	150	900.0	12.0	44.0	.00
209	140	145	900.0	30.0	110.0	.00
210	134	135	900.0	12.0	47.0	.00
211	140	134	600.0	12.0	49.0	.00
212	134	128	600.0	12.0	49.0	.00
213	133	135	1600.0	20.0	110.0	.00
214	128	136	1300.0	12.0	55.0	.00
215	128	136	1300.0	36.0	110.0	.00
216	128	124	600.0	12.0	49.0	.00
217	124	129	1800.0	12.0	52.0	.00
218	124	116	600.0	12.0	49.0	.00
219	124	112	2800.0	12.0	52.0	.00
220	116	117	1700.0	16.0	53.0	.00
221	116	125	900.0	12.0	48.0	.00
222	116	114	1300.0	12.0	49.0	.00
223	114	115	900.0	12.0	49.0	.00
224	135	145	600.0	16.0	112.0	.00
225	145	150	700.0	16.0	112.0	.00
226	150	162	600.0	16.0	112.0	.00
227	162	163	450.0	12.0	49.0	.00
228	163	164	500.0	12.0	90.0	.00
229	162	164	600.0	12.0	93.0	.00
230	150	158	600.0	12.0	44.0	.00
231	145	146	450.0	30.0	110.0	.00
232	135	141	450.0	20.0	110.0	.00
233	141	136	600.0	30.0	74.0	.00
234	141	146	600.0	30.0	74.0	.00
235	146	147	500.0	24.0	110.0	.00
236	146	158	800.0	30.0	69.0	.00
237	147	159	700.0	24.0	110.0	.00
238	158	164	700.0	30.0	69.0	.00
239	159	167	1000.0	20.0	110.0	.00
240	164	167	700.0	12.0	92.0	.00
241	164	176	800.0	30.0	69.0	.00
242	163	178	1050.0	12.0	49.0	.00
243	176	177	500.0	12.0	49.0	.00
244	167	177	400.0	20.0	110.0	.00
245	177	168	500.0	12.0	103.0	.00
246	167	168	450.0	12.0	92.0	.00
247	167	168	450.0	16.0	98.0	.00
248	168	169	700.0	16.0	98.0	.00
249	168	169	700.0	12.0	93.0	.00
250	159	165	1600.0	12.0	44.0	.00
251	141	160	2400.0	12.0	110.0	.00
252	136	142	2100.0	12.0	64.0	.00
253	169	165	600.0	12.0	104.0	.00
254	165	142	1900.0	12.0	49.0	.00
255	142	143	700.0	12.0	61.0	.00
256	142	144	350.0	12.0	66.0	.00
257	165	166	300.0	12.0	44.0	.00
258	169	170	300.0	16.0	98.0	.00
259	169	170	300.0	12.0	93.0	.00
260	170	175	900.0	20.0	110.0	.00
261	170	171	600.0	20.0	110.0	.00
262	171	160	1200.0	20.0	110.0	.00
263	160	144	600.0	12.0	95.0	.00
264	144	161	1000.0	12.0	66.0	.00
265	161	174	1200.0	12.0	49.0	.00
266	174	173	1000.0	12.0	90.0	.00
267	172	174	300.0	12.0	44.0	.00
268	173	172	600.0	12.0	50.0	.00
269	171	172	400.0	12.0	44.0	.00
270	170	173	400.0	12.0	93.0	.00
271	170	173	400.0	16.0	98.0	.00
272	176	179	400.0	30.0	69.0	.00
273	179	178	500.0	12.0	87.0	.00

274	178	180	1000.0	12.0	49.0	.00
275	179	181	1000.0	30.0	69.0	.00
276	177	182	1400.0	20.0	110.0	.00
277	169	183	1000.0	16.0	90.0	.00
278	182	183	1000.0	12.0	130.0	.00
279	181	182	500.0	12.0	50.0	.00
280	181	180	500.0	12.0	50.0	.00
281	180	189	1000.0	12.0	49.0	.00
282	181	188	1000.0	30.0	69.0	.00
283	182	187	1000.0	20.0	110.0	.00
284	183	184	600.0	16.0	90.0	.00
285	184	185	600.0	16.0	67.0	.00
286	184	193	1000.0	16.0	90.0	.00
287	185	193	300.0	16.0	110.0	.00
288	185	186	350.0	12.0	44.0	.00
289	193	192	300.0	16.0	110.0	.00
290	186	187	350.0	12.0	44.0	.00
291	192	191	500.0	12.0	49.0	.00
292	186	192	300.0	12.0	47.0	.00
293	187	191	300.0	20.0	110.0	.00
294	187	188	500.0	16.0	50.0	.00
295	190	191	500.0	20.0	110.0	.00
296	188	190	300.0	30.0	69.0	.00
297	188	189	500.0	16.0	50.0	.00
298	189	194	2600.0	12.0	44.0	.00
299	190	194	2200.0	30.0	84.0	.00
300	190	195	2600.0	20.0	110.0	.00
301	194	195	500.0	12.0	44.0	.00
302	195	196	400.0	12.0	44.0	.00
303	195	196	400.0	20.0	110.0	.00
304	194	198	1400.0	30.0	84.0	.00
305	196	200	1700.0	10.0	51.0	.00
306	196	197	300.0	12.0	49.0	.00
307	197	198	700.0	12.0	46.0	.00
308	198	199	300.0	12.0	46.0	.00
309	199	200	400.0	12.0	46.0	.00
310	199	201	400.0	12.0	50.0	.00
311	198	201	400.0	20.0	110.0	.00
312	198	206	1300.0	30.0	84.0	.00
313	197	204	1400.0	12.0	49.0	.00
314	204	205	1900.0	16.0	52.0	.00
315	192	205	2800.0	16.0	110.0	.00
316	205	213	500.0	16.0	72.0	.00
317	213	215	1600.0	16.0	72.0	.00
318	213	214	1500.0	12.0	92.0	.00
319	215	216	400.0	12.0	49.0	.00
320	214	216	300.0	12.0	49.0	.00
321	204	214	350.0	12.0	49.0	.00
322	204	203	1000.0	16.0	52.0	.00
323	214	217	1000.0	12.0	92.0	.00
324	216	217	1300.0	12.0	62.0	.00
325	217	203	350.0	12.0	50.0	.00
326	201	203	600.0	12.0	50.0	.00
327	203	206	600.0	16.0	52.0	.00
328	201	206	900.0	20.0	110.0	.00
329	200	202	1700.0	12.0	50.0	.00
330	206	207	1200.0	16.0	52.0	.00
331	206	208	1400.0	24.0	110.0	.00
332	206	209	1500.0	16.0	53.0	.00
333	208	209	400.0	16.0	50.0	.00
334	208	210	500.0	24.0	110.0	.00
LINE 334 IS CLOSED						
335	209	211	500.0	16.0	50.0	.00
LINE 335 IS CLOSED						
336	210	211	400.0	20.0	110.0	.00
337	211	212	900.0	16.0	67.0	.00
338	210	212	500.0	16.0	65.0	.00
339	212	218	750.0	16.0	51.0	.00
340	218	219	350.0	16.0	51.0	.00
341	212	221	3300.0	12.0	63.0	.00
342	218	220	3300.0	16.0	89.0	.00
343	219	222	3300.0	12.0	49.0	.00

344	221	220	750.0	12.0	67.0	.00	
345	220	222	350.0	12.0	67.0	.00	
346	221	223	2400.0	12.0	63.0	.00	
347	223	224	1750.0	12.0	50.0	.00	
348	222	224	2350.0	12.0	49.0	.00	
349	224	225	500.0	12.0	49.0	.00	
350	151	157	300.0	12.0	98.0	.00	
351	158	159	300.0	12.0	44.0	.00	
352	228	210	400.0	36.0	110.0	.00	
353	208	227	400.0	36.0	110.0	.00	
354	227	228	400.0	36.0	110.0	.00	

THERE IS A CHECK VALVE IN LINE NUMBER 354

355	0	228	10.0	44.0	110.0	.00	138.00

A SUCCESSFUL GEOMETRIC VERIFICATION HAS BEEN COMPLETED

JUNCTION NUMBER	DEMAND	ELEVATION	CONNECTING PIPES				
1	354.78	23.00	1	2			
2	354.78	48.00	2	3	4		
3	101.09	25.00	3				
4	202.18	15.00	4	5			
5	105.95	30.00	5	6			
6	185.65	2.00	6	7			
7	264.38	20.00	7	8			
8	132.19	74.00	9	10	13	22	
9	132.19	81.00	10	11			
10	105.95	39.00	11	12			
11	185.65	24.00	8	12	16		
12	.00	94.00	19	20	21	26	27
13	52.49	71.00	21	22	23		
14	52.49	67.00	23	24			
15	177.88	46.00	24	25			
16	330.48	82.00	13	14	15	25	
17	679.43	58.00	14	15	16	17	
18	254.66	72.00	17	18	37		
19	441.29	44.00	18				
20	.00	40.00	26	27	28	29	
21	.00	37.00	28	29	30	31	
22	.00	10.00	31	32	48	49	
23	226.48	6.00	32	33	34		
24	226.48	8.00	33				
25	105.95	19.00	34	35	42		
26	.00	38.00	35	36	39	43	
27	127.33	60.00	36	37	38		
28	.00	50.00	38	39	40		
29	105.95	41.00	40	41	59		
30	12.64	107.00	41				
31	119.56	5.00	42	44	45		
32	.00	3.00	43	44			
33	.00	1.00	45	57			
34	.00	2.00	57	58	60	73	
35	121.50	5.00	58	59	61		
36	.00	5.00	61	62	63		
37	.00	5.00	60	63	64	65	
38	335.34	13.00	62	68			
39	.00	4.00	64	66	69		
40	121.50	6.00	65	66	67		
41	.00	8.00	67				
42	.00	20.00	68	69	70		
43	243.97	18.00	70	71	72		
44	62.21	2.00	71				
45	211.90	30.00	72				
46	17.50	3.00	73				
47	.00	134.00	30	46	47		
48	.00	27.00	46	50	80		
49	.00	28.00	48	50	51	85	
50	.00	16.00	49	51	52	53	87
51	105.95	32.00	53	54	74		
52	.00	1.00	54	55	56		
53	119.56	2.00	55	56			
54	318.82	20.00	52	74	75	79	

55	53.46	6.00	75	76	77	78			
56	.00	6.00	76						
57	85.54	4.00	77						
58	321.73	39.00	47	81	83	84			
59	.00	40.00	80	81	82	88			
60	35.96	46.00	82						
61	257.58	41.00	84	86	93				
62	.00	30.00	83	87	96				
63	178.85	42.00	88	89	93	94	95		
64	142.88	62.00	89	90	91	92			
65	35.96	66.00	90						
66	142.88	77.00	92						
67	.00	30.00	85	86	97				
68	32.08	25.00	79	98					
69	142.88	50.00	91	109					
70	53.46	28.00	98	99	102				
71	266.33	30.00	78	99	100				
72	.00	30.00	100	101	121				
73	.00	1.00	101						
74	.00	70.00	97	103					
75	128.30	70.00	96	104	105				
76	128.30	18.00	95	105	106	107			
77	178.85	36.00	94	107	108				
78	32.08	14.00	102	119	120				
79	53.46	5.00	120	121	122				
80	.00	11.00	106	110	112				
81	423.79	15.00	108	110	111	139			
82	158.44	36.00	109	111					
83	192.46	50.00	112	113	114				
84	.00	64.00	103	113	116				
85	32.08	3.00	122	124	129				
86	95.26	2.00	123	124	128				
87	.00	4.00	118	119	123	125			
88	.00	6.00	117	118	126				
89	128.30	64.00	104	115	116	117	134	135	
90	158.44	54.00	114	115	136				
91	199.26	13.00	138	139	140	141			
92	190.51	36.00	140						
93	.00	2.00	125	126	127				
94	32.08	5.00	131						
95	274.10	2.00	127	128	133				
96	131.22	1.00	133	171	181				
97	.00	7.00	134	135	150	160			
98	190.51	9.00	137	138	142	147			
99	317.84	16.00	141	142	143				
100	105.95	9.00	136	137	148	149			
101	.00	9.00	150	151					
102	137.05	6.00	159	160	161				
103	.00	5.00	158	159	162				
104	53.46	1.00	129	130	131	132			
105	21.38	1.00	130						
106	32.08	1.00	132						
107	47.63	7.00	161	170	171	180			
108	137.05	14.00	148	149	151	152	158	163	164
109	105.95	19.00	143	144	146				
110	52.49	23.00	144	145					
111	52.49	25.00	147	152	153	165			
112	190.51	6.00	162	169	170	219			
113	47.63	1.00	180						
114	131.22	1.00	181	222	223				
115	196.34	1.00	223						
116	.00	1.00	218	220	221	222			
117	131.22	1.00	220						
118	.00	5.00	163	164	169	172	182	183	
119	190.51	35.00	153	155	166	167			
120	.00	35.00	146	154					
121	190.51	42.00	145	155	157	168			
122	.00	48.00	154	157					
123	.00	6.00	165	172	173	179			
124	262.44	2.00	216	217	218	219			
125	327.56	12.00	221						
126	.00	15.00	166	167	173	174	177	178	

127	297.43	5.00	179	184	187			
128	.00	4.00	182	183	212	214	215	216
129	105.95	45.00	217					
130	173.02	10.00	177	178	185	186	187	188
131	.00	29.00	168	174	175	176		
132	297.43	10.00	176	188	189	192		
133	.00	4.00	186	213				
134	376.16	6.00	184	210	211	212		
135	.00	15.00	210	213	224	232		
136	131.22	39.00	214	215	233	252		
137	.00	36.00	175	189	190	191		
138	.00	29.00	190	191	193	195		
139	173.02	24.00	192	204	205	208		
140	179.32	20.00	185	204	209	211		
141	.00	29.00	232	233	234	251		
142	211.90	40.00	252	254	255	256		
143	264.38	1.00	255					
144	1265.67	20.00	256	263	264			
145	.00	20.00	209	224	225	231		
146	126.36	17.00	231	234	235	236		
147	105.95	14.00	235	237				
148	.00	24.00	193	194	203			
149	376.16	30.00	203	205	206	207		
150	.00	17.00	208	225	226	230		
151	.00	30.00	194	196	198	350		
152	.00	30.00	198	199				
153	.00	44.00	199	200	202			
154	173.02	74.00	202					
155	.00	45.00	156	195	196	197		
156	126.36	50.00	197					
157	.00	44.00	200	201	350			
158	173.02	17.00	230	236	238	351		
159	105.95	17.00	237	239	250	351		
160	423.79	5.00	251	262	263			
161	317.84	1.00	264	265				
162	.00	35.00	207	226	227	229		
163	221.62	39.00	206	227	228	242		
164	138.02	24.00	228	229	238	240	241	
165	423.79	3.00	250	253	254	257		
166	32.08	2.00	257					
167	158.44	13.00	239	240	244	246	247	
168	105.95	5.00	245	246	247	248	249	
169	105.95	7.00	248	249	253	258	259	277
170	105.95	10.00	258	259	260	261	270	271
171	105.95	2.00	261	262	269			
172	105.95	1.00	267	268	269			
173	105.95	1.00	266	268	270	271		
174	211.90	1.00	265	266	267			
175	414.07	1.00	260					
176	.00	24.00	241	243	272			
177	276.05	13.00	243	244	245	276		
178	221.62	39.00	242	273	274			
179	138.02	13.00	272	273	275			
180	248.83	28.00	274	280	281			
181	138.02	6.00	275	279	280	282		
182	248.83	4.00	276	278	279	283		
183	.00	1.00	277	278	284			
184	221.62	1.00	284	285	286			
185	138.02	3.00	285	287	288			
186	.00	4.00	288	290	292			
187	138.02	12.00	283	290	293	294		
188	84.56	30.00	282	294	296	297		
189	138.02	30.00	281	297	298			
190	.00	70.00	295	296	299	300		
191	.00	35.00	291	293	295			
192	348.95	12.00	289	291	292	315		
193	.00	3.00	286	287	289			
194	.00	70.00	298	299	301	304		
195	.00	57.00	300	301	302	303		
196	.00	37.00	302	303	305	306		
197	.00	30.00	306	307	313			
198	.00	16.00	304	307	308	311	312	

199	.00	22.00	308	309	310			
200	.00	75.00	305	309	329			
201	.00	18.00	310	311	326	328		
202	99.42	105.00	329					
203	.00	3.00	322	325	326	327		
204	264.38	4.00	313	314	321	322		
205	174.96	1.00	314	315	316			
206	174.96	10.00	312	327	328	330	331	332
207	174.96	90.00	330					
208	.00	91.00	331	333	334	353		
209	.00	58.00	332	333	335			
210	.00	80.00	334	336	338	352		
211	.00	50.00	335	336	337			
212	.00	75.00	337	338	339	341		
213	174.96	1.00	316	317	318			
214	.00	2.00	318	320	321	323		
215	174.96	1.00	317	319				
216	.00	1.00	319	320	324			
217	174.96	2.00	323	324	325			
218	.00	83.00	339	340	342			
219	.00	88.00	340	343				
220	153.58	21.00	342	344	345			
221	460.73	15.00	341	344	346			
222	460.73	30.00	343	345	348			
223	233.28	4.00	346	347				
224	153.58	22.00	347	348	349			
225	79.70	30.00	349					
226	.00	60.00	156	201				
227	.00	125.00	353	354				
228	.00	125.00	352	354	355			

OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD
10 VALUES ARE OUTPUT FOR MAXIMUM AND MINIMUM PRESSURES

THIS SYSTEM HAS 355 PIPES WITH 228 JUNCTIONS , 123 LOOPS AND   5 FGNS

A SUMMARY OF CONDITIONS SPECIFIED FOR THE NEXT SIMULATION FOLLOWS

THE DEMANDS ARE CHANGED FROM ORIGINAL VALUES BY A FACTOR =   2.25

THE RESULTS ARE OBTAINED AFTER 4 TRIALS WITH AN ACCURACY = .00067

PIPE NO.	NODE NOS.		FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1	0	1	1915.14	16.70	.00	.00	5.43	18.56
2	1	2	1116.88	30.95	.00	.00	3.17	11.90
3	2	3	227.45	.42	.00	.00	.65	.35
4	2	4	91.17	.05	.00	.00	.26	.03
5	4	5	-363.73	-1.49	.00	.00	-1.03	-.53
6	5	6	-602.12	-.37	.00	.00	-.76	-.19
7	6	7	-1019.83	-1.18	.00	.00	-1.63	-1.07
8	7	11	-1614.69	-9.00	.00	.00	-2.58	-3.33
9	0	8	8111.25	6.84	.00	.00	5.75	5.70
10	8	9	1176.66	11.14	.00	.00	3.34	12.37
11	9	10	879.24	17.27	.00	.00	2.49	4.49
12	10	11	640.85	.41	.00	.00	1.02	.69
13	8	16	6721.35	15.30	.00	.00	4.77	4.03
14	16	17	500.57	4.54	.00	.00	1.42	3.24
15	16	17	5978.21	4.54	.00	.00	4.24	3.24
16	11	17	-1391.55	-8.98	.00	.00	-2.22	-2.90
17	17	18	3558.51	2.71	.00	.00	3.63	3.01
18	18	19	992.90	9.21	.00	.00	1.58	1.84
19	0	12	20776.50	3.91	.00	.00	4.38	1.70
20	0	12	26117.98	3.91	.00	.00	4.63	1.70
21	12	13	1221.63	2.76	.00	.00	1.95	4.61
22	8	13	-84.18	-.17	.00	.00	-.24	-.09

23	13	14	1019.35	3.95	.00	.00	1.63	3.29
24	14	15	901.25	5.02	.00	.00	2.56	5.02
25	15	16	501.02	6.49	.00	.00	1.42	3.25
26	12	20	20235.23	1.13	.00	.00	4.27	1.62
27	12	20	25437.62	1.13	.00	.00	4.51	1.62
28	20	21	25437.62	1.78	.00	.00	4.51	1.62
29	20	21	20235.23	1.78	.00	.00	4.27	1.62
30	21	47	20452.98	5.12	.00	.00	4.32	1.65
31	21	22	25219.87	6.06	.00	.00	4.47	1.59
32	22	23	2593.57	3.85	.00	.00	4.14	9.63
33	23	24	509.58	2.95	.00	.00	1.45	1.97
34	23	25	1574.41	11.93	.00	.00	2.51	3.73
35	25	26	825.21	1.52	.00	.00	1.32	1.13
36	26	27	-502.40	-.18	.00	.00	-.80	-.22
37	27	18	-1992.62	-.62	.00	.00	-2.03	-1.03
38	27	28	1203.73	.83	.00	.00	1.92	2.77
39	26	28	934.87	.65	.00	.00	1.49	1.42
40	28	29	2138.60	2.41	.00	.00	3.41	8.03
41	29	30	28.44	.01	.00	.00	.08	.01
42	25	31	510.81	2.43	.00	.00	1.45	1.57
43	26	32	392.75	.33	.00	.00	.63	.14
44	32	31	392.75	.58	.00	.00	1.11	.57
45	31	33	634.55	5.63	.00	.00	1.80	2.35
46	47	48	4968.53	3.45	.00	.00	3.52	2.30
47	47	58	15484.44	4.59	.00	.00	4.62	2.29
48	22	49	22154.57	3.51	.00	.00	3.93	1.25
49	22	50	471.72	6.15	.00	.00	1.34	2.41
50	48	49	605.76	1.00	.00	.00	.97	.74
51	49	50	1950.68	2.64	.00	.00	3.11	2.93
52	50	54	1642.96	17.38	.00	.00	2.62	5.35
53	50	51	759.82	15.81	.00	.00	2.16	8.32
54	51	52	269.01	.78	.00	.00	.76	.78
55	52	53	136.44	.15	.00	.00	.39	.18
56	52	53	132.57	.15	.00	.00	.38	.21
57	33	34	634.55	8.43	.00	.00	1.80	3.83
58	34	35	-704.24	-.62	.00	.00	-1.12	-1.03
59	35	29	-1871.77	-11.30	.00	.00	-2.99	-6.28
60	34	37	1299.41	.82	.00	.00	2.07	1.71
61	35	36	894.16	1.32	.00	.00	2.54	5.07
62	36	38	702.01	2.91	.00	.00	1.99	3.24
63	36	37	192.15	.12	.00	.00	.55	.20
64	37	39	1056.30	.78	.00	.00	1.69	1.17
65	37	40	435.26	.69	.00	.00	1.23	.69
66	39	40	-161.88	-.09	.00	.00	-.46	-.11
67	40	41	.00	.00	.00	.00	.00	.00
68	38	42	-52.50	-.03	.00	.00	-.15	-.02
69	39	42	1218.18	1.98	.00	.00	1.94	1.52
70	42	43	1165.68	.91	.00	.00	1.86	1.40
71	43	44	139.97	.02	.00	.00	.22	.02
72	43	45	476.77	.51	.00	.00	.76	.16
73	34	46	39.38	.01	.00	.00	.06	.00
74	51	54	252.42	1.57	.00	.00	.72	1.12
75	54	55	375.68	3.28	.00	.00	1.07	2.34
76	55	56	.00	.00	.00	.00	.00	.00
77	55	57	192.46	.49	.00	.00	.55	.32
78	55	71	62.93	.27	.00	.00	.18	.10
79	54	68	802.36	1.77	.00	.00	1.28	.76
80	48	59	4362.78	1.36	.00	.00	3.09	1.81
81	58	59	507.96	.22	.00	.00	.81	.88
82	59	60	80.91	.01	.00	.00	.13	.03
83	58	62	625.41	2.51	.00	.00	1.00	1.29
84	58	61	13627.18	1.09	.00	.00	4.07	1.81
85	49	67	20809.65	1.23	.00	.00	3.69	1.12
86	61	67	28.91	.00	.00	.00	.01	.00
87	50	62	19.66	.01	.00	.00	.06	.01
88	59	63	4789.83	2.36	.00	.00	3.40	2.15
89	63	64	578.59	12.72	.00	.00	1.64	6.06
90	64	65	80.91	.05	.00	.00	.23	.05
91	64	69	-145.28	-.22	.00	.00	-.41	-.12
92	64	66	321.48	1.02	.00	.00	.91	2.04
93	61	63	13018.71	1.50	.00	.00	3.88	1.66
94	63	77	4113.91	5.68	.00	.00	2.92	1.62

95	63	76	12713.63	3.66	.00	.00	3.79	1.59
96	62	75	645.07	4.24	.00	.00	1.03	1.51
97	67	74	20838.56	3.93	.00	.00	4.40	1.71
98	68	70	730.18	.83	.00	.00	1.17	1.19
99	70	71	421.08	.94	.00	.00	1.19	1.17
100	71	72	-115.23	-.23	.00	.00	-.33	-.25
101	72	73	.00	.00	.00	.00	.00	.00
102	70	78	188.82	.22	.00	.00	.30	.10
103	74	84	20838.56	4.10	.00	.00	4.40	1.71
104	75	89	659.37	3.63	.00	.00	1.05	1.58
105	75	76	-302.98	-.50	.00	.00	-.48	-.32
106	76	80	11405.85	2.21	.00	.00	3.40	1.30
107	76	77	716.12	2.01	.00	.00	1.14	1.55
108	77	81	4427.62	3.16	.00	.00	3.14	1.86
109	69	82	-466.76	-2.76	.00	.00	-1.32	-.92
110	80	81	1557.27	2.96	.00	.00	1.59	2.28
111	81	82	823.25	.91	.00	.00	.84	.70
112	80	83	9848.59	.91	.00	.00	3.10	1.13
113	83	84	-4845.76	-.24	.00	.00	-1.53	-.30
114	83	90	14261.31	1.01	.00	.00	4.49	2.25
115	89	90	42.64	.00	.00	.00	.07	.01
116	84	89	15992.80	1.25	.00	.00	5.04	2.78
117	89	88	1583.23	10.13	.00	.00	2.53	4.60
118	88	87	833.86	1.83	.00	.00	1.33	1.40
119	87	78	221.77	.38	.00	.00	.35	.21
120	78	79	338.41	.39	.00	.00	.54	.46
121	72	79	-115.23	-.10	.00	.00	-.18	-.07
122	79	85	102.89	.05	.00	.00	.16	.06
123	87	86	524.40	.71	.00	.00	.84	.59
124	86	85	282.04	.10	.00	.00	.45	.19
125	87	93	87.69	.04	.00	.00	.14	.04
126	88	93	749.37	1.86	.00	.00	1.20	1.86
127	93	95	837.06	.74	.00	.00	1.34	2.45
128	95	86	-28.03	-.06	.00	.00	-.08	-.02
129	85	104	312.75	3.77	.00	.00	.89	1.79
130	104	105	48.10	.05	.00	.00	.14	.06
131	104	94	72.18	.09	.00	.00	.20	.05
132	104	106	72.18	.14	.00	.00	.20	.10
133	95	96	248.36	.21	.00	.00	.40	.26
134	89	97	13955.53	2.81	.00	.00	4.40	2.16
135	89	97	782.10	2.81	.00	.00	1.25	2.16
136	90	100	13947.46	4.32	.00	.00	4.40	2.16
137	100	98	-97.40	-.05	.00	.00	-.16	-.04
138	91	98	443.50	2.21	.00	.00	1.26	1.01
139	81	91	4208.11	1.01	.00	.00	2.98	1.69
140	91	92	428.65	3.75	.00	.00	1.22	2.88
141	91	99	2887.63	1.89	.00	.00	2.05	.84
142	99	98	386.84	.32	.00	.00	.62	.53
143	99	109	1785.65	.26	.00	.00	1.27	.35
144	109	110	378.20	1.32	.00	.00	1.07	2.21
145	110	121	260.10	2.49	.00	.00	.74	1.56
146	109	120	1169.06	.25	.00	.00	.83	.16
147	98	111	304.29	2.90	.00	.00	.86	1.53
148	100	108	13543.50	1.43	.00	.00	4.27	2.05
149	100	108	262.97	1.43	.00	.00	.75	1.30
150	97	101	13247.53	1.57	.00	.00	4.18	1.96
151	101	108	13247.53	1.37	.00	.00	4.18	1.96
152	108	111	13469.87	1.42	.00	.00	4.02	1.77
153	111	119	12932.53	1.72	.00	.00	4.85	2.87
154	120	122	1169.06	.63	.00	.00	.83	.50
155	119	121	-579.65	-.87	.00	.00	-.92	-1.34
156	226	155	-157.37	-.03	.00	.00	-.25	-.10
157	121	122	-1169.06	-2.94	.00	.00	-1.87	-4.90
158	108	103	182.63	.40	.00	.00	.52	.66
159	103	102	-225.57	-.59	.00	.00	-.64	-.98
160	97	102	1490.09	2.76	.00	.00	2.38	6.89
161	102	107	956.16	4.54	.00	.00	1.53	3.03
162	103	112	408.20	3.95	.00	.00	1.16	2.63
163	108	118	12758.46	3.30	.00	.00	4.02	1.83
164	108	118	334.68	3.30	.00	.00	.95	2.20
165	111	123	723.53	2.81	.00	.00	1.15	1.87
166	119	126	9131.23	2.41	.00	.00	3.43	1.51

167	119	126	3952.30	2.41	.00	.00	2.80	1.51
168	121	131	420.86	6.07	.00	.00	1.19	3.80
169	112	118	-697.68	-1.05	.00	.00	-1.11	-1.75
170	112	107	42.19	.01	.00	.00	.07	.01
171	107	96	784.02	2.82	.00	.00	1.25	2.17
172	118	123	600.94	.93	.00	.00	.96	1.33
173	123	126	790.28	1.32	.00	.00	1.26	2.20
174	126	131	1089.44	2.80	.00	.00	1.74	4.00
175	131	137	1023.07	5.33	.00	.00	1.63	3.56
176	131	132	487.24	4.48	.00	.00	1.38	4.98
177	126	130	4568.81	1.77	.00	.00	3.24	1.97
178	126	130	8215.55	1.77	.00	.00	3.73	1.97
179	123	127	534.20	4.70	.00	.00	1.52	5.23
180	107	113	107.17	.04	.00	.00	.17	.05
181	96	114	737.14	23.71	.00	.00	2.09	8.78
182	118	128	11520.64	4.25	.00	.00	3.63	1.52
183	118	128	273.87	4.25	.00	.00	.78	1.52
184	127	134	245.31	2.35	.00	.00	.70	1.24
185	130	140	8676.04	3.92	.00	.00	3.94	2.18
186	130	133	2658.36	1.23	.00	.00	1.89	.72
187	127	130	-380.33	-1.61	.00	.00	-1.08	-2.68
188	130	132	680.33	5.51	.00	.00	1.93	7.86
189	132	137	270.17	.85	.00	.00	.77	1.42
190	137	138	395.70	.51	.00	.00	1.12	.85
191	137	138	897.55	.51	.00	.00	1.43	.85
192	132	139	228.17	2.32	.00	.00	.65	1.22
193	138	148	790.10	.61	.00	.00	2.24	3.05
194	148	151	170.46	.10	.00	.00	.48	.16
195	138	155	503.14	.69	.00	.00	.80	.86
196	151	155	-61.47	-.02	.00	.00	-.17	-.09
197	155	156	284.31	.68	.00	.00	.81	1.50
198	151	152	94.82	.04	.00	.00	.27	.20
199	152	153	94.82	.06	.00	.00	.27	.19
200	153	157	-294.48	-.06	.00	.00	-.47	-.32
201	157	226	-157.37	-.02	.00	.00	-.25	-.10
202	153	154	389.29	.78	.00	.00	1.10	2.59
203	148	149	619.64	1.94	.00	.00	1.76	1.94
204	140	139	576.87	3.90	.00	.00	1.64	5.58
205	139	149	386.39	1.59	.00	.00	1.10	2.66
206	149	163	282.93	2.98	.00	.00	.80	1.49
207	149	162	-123.26	-.09	.00	.00	-.35	-.10
208	139	150	29.35	.02	.00	.00	.08	.03
209	140	145	7647.06	1.55	.00	.00	3.47	1.72
210	134	135	59.82	.08	.00	.00	.17	.09
211	140	134	48.64	.03	.00	.00	.14	.06
212	134	128	-612.22	-3.74	.00	.00	-1.74	-6.23
213	133	135	2658.36	2.81	.00	.00	2.71	1.76
214	128	136	269.48	1.43	.00	.00	.76	1.10
215	128	136	9686.85	1.43	.00	.00	3.05	1.10
216	128	124	1225.96	13.52	.00	.00	3.48	22.53
217	124	129	238.39	1.75	.00	.00	.68	.97
218	124	116	1032.13	9.83	.00	.00	2.93	16.38
219	124	112	-635.05	-16.71	.00	.00	-1.80	-5.97
220	116	117	295.24	.58	.00	.00	.47	.34
221	116	125	737.01	8.21	.00	.00	2.09	9.12
222	116	114	-.13	.00	.00	.00	.00	.00
223	114	115	441.76	3.06	.00	.00	1.25	3.40
224	135	145	1780.19	1.44	.00	.00	2.84	2.40
225	145	150	2148.90	2.38	.00	.00	3.43	3.39
226	150	162	1808.88	1.48	.00	.00	2.89	2.47
227	162	163	643.11	3.07	.00	.00	1.82	6.82
228	163	164	-59.39	-.01	.00	.00	-.17	-.03
229	162	164	1042.52	3.06	.00	.00	2.96	5.09
230	150	158	369.37	1.79	.00	.00	1.05	2.98
231	145	146	7278.35	.71	.00	.00	3.30	1.57
232	135	141	937.99	.11	.00	.00	.96	.26
233	141	136	-8286.14	-2.50	.00	.00	-3.76	-4.17
234	141	146	7403.23	2.03	.00	.00	3.36	3.38
235	146	147	6521.24	1.90	.00	.00	4.62	3.81
236	146	158	7876.03	3.46	.00	.00	3.57	4.32
237	147	159	6282.85	2.49	.00	.00	4.46	3.55
238	158	164	7477.94	2.75	.00	.00	3.39	3.93

239	159	167	5685.85	7.18	.00	.00	5.81	7.18
240	164	167	1285.77	5.36	.00	.00	3.65	7.66
241	164	176	6864.76	2.68	.00	.00	3.12	3.35
242	163	178	486.78	4.28	.00	.00	1.38	4.07
243	176	177	657.27	3.55	.00	.00	1.86	7.10
244	167	177	2978.74	.87	.00	.00	3.04	2.17
245	177	168	948.31	1.77	.00	.00	2.69	3.54
246	167	168	1112.13	2.64	.00	.00	3.15	5.86
247	167	168	2524.25	2.64	.00	.00	4.03	5.86
248	168	169	3007.06	5.67	.00	.00	4.80	8.10
249	168	169	1339.25	5.67	.00	.00	3.80	8.10
250	159	165	736.77	17.14	.00	.00	2.09	10.71
251	141	160	1820.91	25.16	.00	.00	5.17	10.48
252	136	142	1374.94	35.68	.00	.00	3.90	16.99
253	169	165	836.47	1.65	.00	.00	2.37	2.75
254	165	142	547.54	9.62	.00	.00	1.55	5.06
255	142	143	594.85	2.75	.00	.00	1.69	3.93
256	142	144	850.85	2.31	.00	.00	2.41	6.60
257	165	166	72.18	.04	.00	.00	.20	.14
258	169	170	2910.44	2.29	.00	.00	4.64	7.62
259	169	170	1296.22	2.29	.00	.00	3.68	7.62
260	170	175	931.66	.23	.00	.00	.95	.25
261	170	171	1771.01	.50	.00	.00	1.81	.83
262	171	160	1187.62	.47	.00	.00	1.21	.39
263	160	144	2055.00	10.32	.00	.00	5.83	17.21
264	144	161	58.09	.05	.00	.00	.16	.05
265	161	174	-657.05	-8.52	.00	.00	-1.86	-7.10
266	174	173	-686.18	-2.49	.00	.00	-1.95	-2.49
267	172	174	447.64	1.28	.00	.00	1.27	4.26
268	173	172	341.03	1.22	.00	.00	.97	2.03
269	171	172	345.00	1.05	.00	.00	.98	2.63
270	170	173	389.98	.33	.00	.00	1.11	.82
271	170	173	875.62	.33	.00	.00	1.40	.82
272	176	179	6207.50	1.11	.00	.00	2.82	2.78
273	179	178	403.65	.50	.00	.00	1.14	.99
274	178	180	391.78	2.72	.00	.00	1.11	2.72
275	179	181	5493.30	2.22	.00	.00	2.49	2.22
276	177	182	2066.59	1.54	.00	.00	2.11	1.10
277	169	183	-935.20	-1.09	.00	.00	-1.49	-1.09
278	182	183	1412.32	4.81	.00	.00	4.01	4.81
279	181	182	459.60	1.76	.00	.00	1.30	3.53
280	181	180	339.08	1.00	.00	.00	.96	2.01
281	180	189	171.00	.59	.00	.00	.49	.59
282	181	188	4384.08	1.46	.00	.00	1.99	1.46
283	182	187	554.00	.10	.00	.00	.57	.10
284	183	184	477.11	.19	.00	.00	.76	.31
285	184	185	-13.73	.00	.00	.00	-.02	.00
286	184	193	-7.80	.00	.00	.00	-.01	.00
287	185	193	26.41	.00	.00	.00	.04	.00
288	185	186	-350.68	-.95	.00	.00	-.99	-2.71
289	193	192	18.61	.00	.00	.00	.03	.00
290	186	187	-757.90	-3.95	.00	.00	-2.15	-11.29
291	192	191	-782.00	-4.90	.00	.00	-2.22	-9.80
292	186	192	407.21	.95	.00	.00	1.16	3.16
293	187	191	-75.16	.00	.00	.00	-.08	.00
294	187	188	-439.28	-.40	.00	.00	-.70	-.80
295	190	191	857.16	.11	.00	.00	.88	.22
296	188	190	3514.33	.29	.00	.00	1.60	.97
297	188	189	240.21	.13	.00	.00	.38	.26
298	189	194	100.66	.70	.00	.00	.29	.27
299	190	194	2032.10	.54	.00	.00	.92	.24
300	190	195	625.07	.31	.00	.00	.64	.12
301	194	195	-172.33	-.36	.00	.00	-.49	-.73
302	195	196	42.79	.02	.00	.00	.12	.06
303	195	196	409.95	.02	.00	.00	.42	.06
304	194	198	2305.09	.43	.00	.00	1.05	.31
305	196	200	102.20	.87	.00	.00	.42	.51
306	196	197	350.54	.67	.00	.00	.99	2.22
307	197	198	-41.14	-.03	.00	.00	-.12	-.05
308	198	199	110.18	.09	.00	.00	.31	.29
309	199	200	121.50	.14	.00	.00	.34	.35
310	199	201	-11.31	.00	.00	.00	-.03	.00

311	198	201	857.20	.09	.00	.00	.88	.22
312	198	206	1296.57	.14	.00	.00	.59	.11
313	197	204	391.68	3.81	.00	.00	1.11	2.72
314	204	205	297.67	.69	.00	.00	.47	.36
315	192	205	422.68	.48	.00	.00	.67	.17
316	205	213	326.69	.12	.00	.00	.52	.24
317	213	215	155.50	.10	.00	.00	.25	.06
318	213	214	-222.47	-.45	.00	.00	-.63	-.30
319	215	216	-238.16	-.43	.00	.00	-.68	-1.08
320	214	216	131.24	.11	.00	.00	.37	.36
321	204	214	230.88	.36	.00	.00	.65	1.02
322	204	203	-731.72	-1.91	.00	.00	-1.17	-1.91
323	214	217	-122.83	-.10	.00	.00	-.35	-.10
324	216	217	-106.92	-.21	.00	.00	-.30	-.16
325	217	203	-623.41	-2.17	.00	.00	-1.77	-6.20
326	201	203	425.87	1.84	.00	.00	1.21	3.06
327	203	206	-929.26	-1.79	.00	.00	-1.48	-2.98
328	201	206	420.02	.05	.00	.00	.43	.06
329	200	202	223.69	1.58	.00	.00	.63	.93
330	206	207	393.66	.73	.00	.00	.63	.61
331	206	208	.00	.00	.00	.00	.00	.00
332	206	209	.00	.00	.00	.00	.00	.00
333	208	209	.00	.00	.00	.00	.00	.00

LINE 334 IS CLOSED
LINE 335 IS CLOSED

336	210	211	1460.46	.23	.00	.00	1.49	.58
337	211	212	1460.46	3.87	.00	.00	2.33	4.30
338	210	212	2008.14	4.10	.00	.00	3.20	8.20
339	212	218	2481.92	14.27	.00	.00	3.96	19.03
340	218	219	544.58	.40	.00	.00	.87	1.15
341	212	221	986.68	31.23	.00	.00	2.80	9.46
342	218	220	1937.34	14.15	.00	.00	3.09	4.29
343	219	222	544.58	16.54	.00	.00	1.54	5.01
344	221	220	-635.07	-2.80	.00	.00	-1.80	-3.73
345	220	222	956.72	2.79	.00	.00	2.71	7.97
346	221	223	585.11	8.63	.00	.00	1.66	3.59
347	223	224	60.23	.14	.00	.00	.17	.08
348	222	224	464.65	8.78	.00	.00	1.32	3.74
349	224	225	179.32	.32	.00	.00	.51	.64
350	151	157	137.11	.03	.00	.00	.39	.11
351	158	159	378.16	.93	.00	.00	1.07	3.11
352	228	210	3468.60	.07	.00	.00	1.09	.16
353	208	227	.00	.00	.00	.00	.00	.00

THE CHECK VALVE IN LINE NUMBER 354 IS CLOSED

355	0	228	3468.60	.00	.00	.00	.73	.06

JUNCTION NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
1	798.26	155.30	23.00	57.33
2	798.26	124.35	48.00	33.08
3	227.45	123.93	25.00	42.87
4	454.90	124.30	15.00	47.36
5	238.39	125.78	30.00	41.51
6	417.71	126.16	2.00	53.80
7	594.85	127.34	20.00	46.51
8	297.43	165.16	74.00	39.50
9	297.43	154.02	81.00	31.64
10	238.39	136.75	39.00	42.36
11	417.71	136.34	24.00	48.68
12	.00	168.09	94.00	32.10
13	118.10	165.32	71.00	40.87
14	118.10	161.37	67.00	40.89
15	400.23	156.35	46.00	47.82
16	743.58	149.86	82.00	29.40
17	1528.72	145.32	58.00	37.84
18	572.98	142.61	72.00	30.60
19	992.90	133.40	44.00	38.74
20	.00	166.95	40.00	55.01
21	.00	165.17	37.00	55.54
22	.00	159.12	10.00	64.62
23	509.58	155.27	6.00	64.68
24	509.58	152.32	8.00	62.54

25	238.39	143.33	19.00	53.88
26	.00	141.81	38.00	44.98
27	286.49	141.99	60.00	35.53
28	.00	141.16	50.00	39.50
29	238.39	138.75	41.00	42.36
30	28.44	138.74	107.00	13.75
31	269.01	140.90	5.00	58.89
32	.00	141.48	3.00	60.01
33	.00	135.26	1.00	58.18
34	.00	126.83	2.00	54.09
35	273.37	127.45	5.00	53.06
36	.00	126.13	5.00	52.49
37	.00	126.01	5.00	52.44
38	754.52	123.22	13.00	47.76
39	.00	125.23	4.00	52.53
40	273.37	125.32	6.00	51.70
41	.00	125.32	8.00	50.84
42	.00	123.25	20.00	44.74
43	548.93	122.34	18.00	45.21
44	139.97	122.32	2.00	52.14
45	476.77	121.83	30.00	39.79
46	39.38	126.82	3.00	53.65
47	.00	160.05	134.00	11.29
48	.00	156.60	27.00	56.16
49	.00	155.61	28.00	55.30
50	.00	152.96	16.00	59.35
51	238.39	137.15	32.00	45.57
52	.00	136.37	1.00	58.66
53	269.01	136.22	2.00	58.16
54	717.35	135.58	20.00	50.09
55	120.28	132.31	6.00	54.73
56	.00	132.31	6.00	54.73
57	192.46	131.82	4.00	55.39
58	723.89	155.46	39.00	50.47
59	.00	155.24	40.00	49.94
60	80.91	155.23	46.00	47.33
61	579.55	154.38	41.00	49.13
62	.00	152.95	30.00	53.28
63	402.41	152.88	42.00	48.05
64	321.48	140.16	62.00	33.87
65	80.91	140.11	66.00	32.11
66	321.48	139.14	77.00	26.93
67	.00	154.38	30.00	53.90
68	72.18	133.81	25.00	47.15
69	321.48	140.38	50.00	39.16
70	120.28	132.98	28.00	45.49
71	599.24	132.04	30.00	44.22
72	.00	132.27	30.00	44.32
73	.00	132.27	1.00	56.88
74	.00	150.44	70.00	34.86
75	288.68	148.71	70.00	34.11
76	288.68	149.22	18.00	56.86
77	402.41	147.20	36.00	48.19
78	72.18	132.76	14.00	51.46
79	120.28	132.37	5.00	55.19
80	.00	147.00	11.00	58.93
81	953.53	144.04	15.00	55.92
82	356.49	143.13	36.00	46.42
83	433.04	146.10	50.00	41.64
84	.00	146.34	64.00	35.68
85	72.18	132.31	3.00	56.04
86	214.34	132.42	2.00	56.51
87	.00	133.13	4.00	55.96
88	.00	134.96	6.00	55.88
89	288.68	145.09	64.00	35.14
90	356.49	145.08	54.00	39.47
91	448.33	143.03	13.00	56.35
92	428.65	139.28	36.00	44.75
93	.00	133.09	2.00	56.81
94	72.18	128.45	5.00	53.50
95	616.73	132.36	2.00	56.49
96	295.24	132.15	1.00	56.83

97	.00	142.28	7.00	58.62
98	428.65	140.81	9.00	57.12
99	715.14	141.13	16.00	54.22
100	238.39	140.76	9.00	57.10
101	.00	140.70	9.00	57.07
102	308.36	139.52	6.00	57.86
103	.00	138.93	5.00	58.04
104	120.28	128.55	1.00	55.27
105	48.10	128.50	1.00	55.25
106	72.18	128.40	1.00	55.21
107	107.17	134.98	7.00	55.46
108	308.36	139.33	14.00	54.31
109	238.39	140.87	19.00	52.81
110	118.10	139.55	23.00	50.50
111	118.10	137.91	25.00	48.93
112	428.65	134.98	6.00	55.89
113	107.17	134.93	1.00	58.04
114	295.24	108.44	1.00	46.56
115	441.76	105.38	1.00	45.23
116	.00	108.44	1.00	46.56
117	295.24	107.86	1.00	46.30
118	.00	136.03	5.00	56.78
119	428.65	136.19	35.00	43.85
120	.00	140.62	35.00	45.77
121	428.65	137.06	42.00	41.19
122	.00	140.00	48.00	39.86
123	.00	135.10	6.00	55.94
124	590.49	118.27	2.00	50.38
125	737.01	100.23	12.00	38.23
126	.00	133.78	15.00	51.47
127	669.22	130.40	5.00	54.34
128	.00	131.79	4.00	55.37
129	238.39	116.52	45.00	30.99
130	389.29	132.01	10.00	52.87
131	.00	130.98	29.00	44.19
132	669.22	126.50	10.00	50.48
133	.00	130.78	4.00	54.94
134	846.36	128.05	6.00	52.89
135	.00	127.97	15.00	48.95
136	295.24	130.36	39.00	39.59
137	.00	125.65	36.00	38.85
138	.00	125.14	29.00	41.66
139	389.29	124.18	24.00	43.41
140	403.47	128.09	20.00	46.84
141	.00	127.86	29.00	42.84
142	476.77	94.68	40.00	23.69
143	594.85	91.92	1.00	39.40
144	2847.76	92.37	20.00	31.36
145	.00	126.53	20.00	46.16
146	284.31	125.83	17.00	47.16
147	238.39	123.92	14.00	47.63
148	.00	124.53	24.00	43.56
149	846.36	122.59	30.00	40.12
150	.00	124.16	17.00	46.43
151	.00	124.44	30.00	40.92
152	.00	124.40	30.00	40.90
153	.00	124.34	44.00	34.81
154	389.29	123.56	74.00	21.48
155	.00	124.45	45.00	34.43
156	284.31	123.78	50.00	31.97
157	.00	124.40	44.00	34.84
158	389.29	122.37	17.00	45.66
159	238.39	121.43	17.00	45.25
160	953.53	102.69	5.00	42.33
161	715.14	92.32	1.00	39.57
162	.00	122.68	35.00	37.99
163	498.64	119.61	39.00	34.93
164	310.55	119.62	24.00	41.44
165	953.53	104.30	3.00	43.90
166	72.18	104.26	2.00	44.31
167	356.49	114.26	13.00	43.88
168	238.39	111.62	5.00	46.20

169	238.39	105.95	7.00	42.88
170	238.39	103.66	10.00	40.59
171	238.39	103.17	2.00	43.84
172	238.39	102.12	1.00	43.82
173	238.39	103.33	1.00	44.34
174	476.77	100.84	1.00	43.26
175	931.66	103.44	1.00	44.39
176	.00	116.94	24.00	40.27
177	621.11	113.39	13.00	43.50
178	498.64	115.33	39.00	33.08
179	310.55	115.83	13.00	44.56
180	559.87	112.61	28.00	36.66
181	310.55	113.61	6.00	46.63
182	559.87	111.85	4.00	46.73
183	.00	107.04	1.00	45.95
184	498.64	106.85	1.00	45.87
185	310.55	106.85	3.00	45.00
186	.00	107.80	4.00	44.98
187	310.55	111.75	12.00	43.23
188	190.26	112.15	30.00	35.60
189	310.55	112.02	30.00	35.54
190	.00	111.86	70.00	18.14
191	.00	111.75	35.00	33.26
192	785.14	106.85	12.00	41.10
193	.00	106.85	3.00	45.00
194	.00	111.32	70.00	17.91
195	.00	111.69	57.00	23.70
196	.00	111.52	37.00	32.29
197	.00	110.86	30.00	35.04
198	.00	110.89	16.00	41.12
199	.00	110.80	22.00	38.48
200	.00	110.66	75.00	15.45
201	.00	110.80	18.00	40.22
202	223.69	109.08	105.00	1.77
203	.00	108.97	3.00	45.92
204	594.85	107.06	4.00	44.66
205	393.66	106.37	1.00	45.66
206	393.66	110.75	10.00	43.66
207	393.66	110.02	90.00	8.68
208	.00	110.75	91.00	8.56
209	.00	110.75	58.00	22.86
210	.00	137.93	80.00	25.10
211	.00	137.70	50.00	38.00
212	.00	133.83	75.00	25.49
213	393.66	106.25	1.00	45.61
214	.00	106.70	2.00	45.37
215	393.66	106.16	1.00	45.57
216	.00	106.59	1.00	45.76
217	393.66	106.80	2.00	45.41
218	.00	119.56	83.00	15.84
219	.00	119.16	88.00	13.50
220	345.55	105.41	21.00	36.58
221	1036.64	102.61	15.00	37.96
222	1036.64	102.62	30.00	31.47
223	524.88	93.98	4.00	38.99
224	345.55	93.84	22.00	31.13
225	179.32	93.52	30.00	27.52
226	.00	124.42	60.00	27.92
227	.00	110.75	125.00	-6.17
228	.00	138.00	125.00	5.63

MAXIMUM PRESSURES

23	509.58	155.27	6.00	64.68
22	.00	159.12	10.00	64.62
24	509.58	152.32	8.00	62.54
32	.00	141.48	3.00	60.01
50	.00	152.96	16.00	59.35
80	.00	147.00	11.00	58.93
31	269.01	140.90	5.00	58.89
52	.00	136.37	1.00	58.66
97	.00	142.28	7.00	58.62
33	.00	135.26	1.00	58.18

MINIMUM PRESSURES

227	.00	110.75	125.00	-6.17
202	223.69	109.08	105.00	1.77
228	.00	138.00	125.00	5.63
208	.00	110.75	91.00	8.56
207	393.66	110.02	90.00	8.68
47	.00	160.05	134.00	11.29
219	.00	119.16	88.00	13.50
30	28.44	138.74	107.00	13.75
200	.00	110.66	75.00	15.45
218	.00	119.56	83.00	15.84

THE NET SYSTEM DEMAND = 60389.51

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1	1915.14
9	8111.25
19	20776.50
20	26117.98
355	3468.60

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 60389.47
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = .00

SUNSET PRESSURE ZONE - MAXIMUM DAY DEMAND

FLOWRATE IS EXPRESSED IN MGD AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

PIPE NO.	NODE NOS.		LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1	0	1	3300.0	60.0	110.0	.00	385.00
2	1	2	600.0	60.0	110.0	.00	
3	2	3	9000.0	16.0	50.0	.00	
4	2	4	2350.0	60.0	110.0	.00	
5	4	22	5450.0	12.0	50.0	.00	
6	4	5	9600.0	60.0	110.0	.00	
7	5	6	1000.0	60.0	110.0	.00	
8	0	6	200.0	60.0	110.0	.00	385.00
9	6	7	600.0	54.0	110.0	.00	
10	5	7	300.0	16.0	77.0	.00	
11	5	9	1900.0	16.0	77.0	.00	
12	7	8	3600.0	54.0	110.0	.00	
13	8	11	1800.0	16.0	67.0	.00	
14	9	10	2700.0	12.0	75.0	.00	
15	8	10	2950.0	16.0	75.0	.00	
16	8	14	3200.0	54.0	110.0	.00	
17	10	12	2850.0	18.0	110.0	.00	
18	12	13	6200.0	16.0	68.0	.00	
19	14	15	1550.0	54.0	110.0	.00	
20	14	18	3600.0	12.0	72.0	.00	
21	15	16	2500.0	12.0	74.0	.00	
22	17	15	1800.0	54.0	110.0	.00	
THERE IS A CHECK VALVE IN LINE NUMBER 22							
23	17	27	4600.0	44.0	110.0	.00	
24	22	17	2700.0	54.0	110.0	.00	
25	18	20	1500.0	12.0	74.0	.00	
26	20	21	1200.0	12.0	66.0	.00	
27	18	19	1600.0	12.0	63.0	.00	
28	23	20	5900.0	12.0	63.0	.00	
29	24	22	2000.0	54.0	110.0	.00	
30	24	26	2250.0	23.0	110.0	.00	
31	24	23	3650.0	30.0	110.0	.00	
32	0	24	100.0	54.0	110.0	.00	385.00
33	0	29	2100.0	60.0	110.0	.00	385.00
34	28	9	2650.0	12.0	75.0	.00	
35	29	28	1900.0	16.0	77.0	.00	
36	29	30	1400.0	60.0	110.0	.00	
37	28	31	2100.0	12.0	75.0	.00	
38	30	32	600.0	16.0	73.0	.00	
39	32	31	1800.0	16.0	77.0	.00	
40	31	25	4100.0	16.0	104.0	.00	
41	32	34	2500.0	16.0	130.0	.00	
42	30	33	2400.0	60.0	110.0	.00	
43	33	34	650.0	30.0	110.0	.00	
44	33	38	4100.0	60.0	110.0	.00	
45	34	35	300.0	16.0	130.0	.00	
46	35	39	3700.0	16.0	57.0	.00	
47	34	37	1750.0	30.0	110.0	.00	
48	35	36	1400.0	16.0	57.0	.00	
49	42	36	3800.0	20.0	110.0	.00	
50	36	37	500.0	30.0	110.0	.00	
51	37	45	3000.0	30.0	110.0	.00	
52	38	39	650.0	30.0	110.0	.00	
53	38	39	650.0	24.0	110.0	.00	
54	38	222	2100.0	36.0	110.0	.00	
55	39	40	650.0	30.0	110.0	.00	
56	39	42	1300.0	24.0	110.0	.00	

57	40	41	900.0	12.0	49.0	.00
58	40	42	650.0	30.0	110.0	.00
59	38	44	3500.0	36.0	110.0	.00
60	42	43	350.0	24.0	110.0	.00
61	45	46	1700.0	20.0	110.0	.00
62	45	47	2000.0	16.0	57.0	.00
63	45	48	1500.0	20.0	110.0	.00
64	46	49	3100.0	20.0	110.0	.00
65	101	50	1700.0	16.0	105.0	.00
66	101	51	650.0	16.0	66.0	.00
67	51	52	850.0	12.0	63.0	.00
68	51	53	1500.0	12.0	63.0	.00
69	51	54	2800.0	16.0	66.0	.00
70	53	54	1300.0	12.0	74.0	.00
71	54	55	650.0	12.0	74.0	.00
72	57	53	1500.0	12.0	63.0	.00
73	54	56	1500.0	16.0	66.0	.00
74	46	57	1300.0	16.0	66.0	.00
75	57	58	650.0	12.0	55.0	.00
76	58	56	650.0	12.0	63.0	.00
77	56	59	1300.0	12.0	63.0	.00
78	59	60	500.0	12.0	63.0	.00
79	62	61	1300.0	16.0	53.0	.00
80	47	62	650.0	16.0	57.0	.00
81	49	101	650.0	16.0	66.0	.00
82	61	59	1700.0	12.0	78.0	.00
83	56	62	1700.0	16.0	66.0	.00
84	47	58	1700.0	12.0	55.0	.00
85	61	63	1500.0	12.0	50.0	.00
86	62	64	1500.0	16.0	66.0	.00
87	64	63	1300.0	12.0	76.0	.00
88	48	64	2700.0	12.0	76.0	.00
89	63	65	950.0	12.0	77.0	.00
90	65	66	1000.0	12.0	95.0	.00
91	65	67	550.0	12.0	77.0	.00
92	64	69	1500.0	16.0	54.0	.00
93	48	70	1500.0	20.0	110.0	.00
94	67	68	700.0	12.0	84.0	.00
95	69	67	1300.0	12.0	84.0	.00
96	70	69	2700.0	12.0	84.0	.00
97	67	73	1700.0	12.0	77.0	.00
98	69	72	1250.0	16.0	54.0	.00
99	70	71	1250.0	20.0	110.0	.00
100	71	72	2700.0	12.0	78.0	.00
101	72	73	1300.0	12.0	78.0	.00
102	73	76	1550.0	12.0	77.0	.00
103	72	75	1600.0	16.0	54.0	.00
104	71	74	1000.0	20.0	110.0	.00
105	43	74	2800.0	30.0	110.0	.00
106	74	78	600.0	30.0	110.0	.00
107	78	86	400.0	30.0	110.0	.00
108	75	76	1550.0	24.0	110.0	.00
109	76	82	600.0	24.0	110.0	.00
110	82	83	450.0	23.5	110.0	.00
111	83	84	900.0	20.0	110.0	.00
112	75	77	350.0	16.0	53.0	.00
113	77	81	1600.0	16.0	66.0	.00
114	79	77	2600.0	12.0	50.0	.00
115	78	79	600.0	12.0	48.0	.00
116	79	80	650.0	12.0	48.0	.00
117	80	85	2450.0	16.0	51.0	.00
118	81	84	1700.0	12.0	105.0	.00
119	84	102	4550.0	20.0	110.0	.00
120	81	103	4900.0	16.0	66.0	.00
121	86	75	2200.0	24.0	110.0	.00
122	85	87	1150.0	16.0	110.0	.00
123	89	85	1400.0	16.0	52.0	.00
124	87	88	450.0	22.0	110.0	.00
125	89	87	1100.0	24.0	110.0	.00
126	90	89	300.0	22.0	110.0	.00
127	43	90	3400.0	24.0	110.0	.00
128	91	90	700.0	24.0	110.0	.00

129	43	91	2400.0	30.0	110.0	.00
130	90	88	1800.0	22.0	110.0	.00
131	88	93	4700.0	24.0	110.0	.00
132	88	92	4000.0	22.0	110.0	.00
133	92	154	1100.0	16.0	110.0	.00
134	92	112	450.0	22.0	110.0	.00
135	92	93	800.0	12.0	44.0	.00
136	92	93	800.0	22.0	110.0	.00
137	93	94	1600.0	22.0	110.0	.00
138	93	96	1050.0	12.0	44.0	.00
139	93	111	500.0	24.0	110.0	.00
140	94	95	600.0	20.0	60.0	.00
141	95	103	1900.0	22.0	110.0	.00
142	103	98	650.0	22.0	110.0	.00
143	103	107	500.0	16.0	66.0	.00
144	96	97	1000.0	12.0	44.0	.00
145	96	110	500.0	12.0	51.0	.00
146	98	99	350.0	22.0	110.0	.00
147	99	102	350.0	22.0	110.0	.00
148	99	100	1300.0	12.0	51.0	.00
149	98	100	1000.0	16.0	54.0	.00
150	100	106	500.0	16.0	54.0	.00
151	102	104	700.0	22.0	110.0	.00
152	102	105	1450.0	20.0	110.0	.00
153	106	105	650.0	24.0	110.0	.00
154	105	125	650.0	24.0	110.0	.00
155	105	121	500.0	16.0	61.0	.00
156	106	120	500.0	16.0	54.0	.00
157	107	106	1600.0	24.0	110.0	.00
158	108	107	1300.0	24.0	110.0	.00
159	108	117	1450.0	16.0	110.0	.00
160	109	108	1050.0	24.0	110.0	.00
161	109	116	1450.0	16.0	54.0	.00
162	110	109	650.0	24.0	110.0	.00
163	111	110	1050.0	24.0	110.0	.00
164	112	111	300.0	24.0	110.0	.00
165	112	113	900.0	22.0	110.0	.00
166	157	112	3700.0	24.0	110.0	.00
167	113	114	550.0	22.0	110.0	.00
168	114	115	1400.0	12.0	45.0	.00
169	114	116	2400.0	16.0	44.0	.00
170	116	117	1050.0	16.0	44.0	.00
171	117	118	700.0	16.0	44.0	.00
172	118	119	650.0	16.0	44.0	.00
173	118	134	1000.0	12.0	109.0	.00
174	119	134	1800.0	12.0	87.0	.00
175	119	120	650.0	16.0	44.0	.00
176	120	131	2400.0	16.0	52.0	.00
177	121	120	650.0	16.0	44.0	.00
178	121	129	2900.0	16.0	61.0	.00
179	122	121	650.0	16.0	44.0	.00
180	125	122	500.0	16.0	54.0	.00
181	122	123	1000.0	16.0	44.0	.00
182	124	123	500.0	16.0	54.0	.00
183	125	124	1000.0	24.0	110.0	.00
184	123	127	2900.0	12.0	42.0	.00
185	124	126	4400.0	16.0	73.0	.00
186	126	127	1000.0	12.0	72.0	.00
187	126	219	1400.0	16.0	77.0	.00
188	127	140	1400.0	12.0	42.0	.00
189	127	128	1300.0	12.0	52.0	.00
190	128	139	1400.0	12.0	52.0	.00
191	129	128	350.0	12.0	52.0	.00
192	129	138	1400.0	16.0	54.0	.00
193	129	130	700.0	12.0	52.0	.00
194	130	137	1400.0	16.0	52.0	.00
195	131	130	500.0	16.0	52.0	.00
196	130	133	1350.0	12.0	52.0	.00
197	131	132	1000.0	12.0	52.0	.00
198	134	220	1000.0	12.0	109.0	.00
199	133	132	900.0	12.0	78.0	.00
200	158	113	3400.0	16.0	79.0	.00

201	133	135	250.0	12.0	52.0	.00
202	133	136	1400.0	12.0	78.0	.00
203	136	148	1000.0	12.0	50.0	.00
204	136	137	1350.0	12.0	50.0	.00
205	137	147	1000.0	16.0	52.0	.00
206	138	137	750.0	12.0	50.0	.00
207	138	146	1000.0	16.0	66.0	.00
208	139	138	350.0	12.0	50.0	.00
209	140	139	1300.0	12.0	50.0	.00
210	140	141	450.0	12.0	42.0	.00
211	142	143	900.0	16.0	106.0	.00
212	142	144	500.0	12.0	77.0	.00
213	146	145	1000.0	16.0	54.0	.00
214	146	147	750.0	16.0	54.0	.00
215	147	148	1350.0	12.0	50.0	.00
216	148	149	1850.0	12.0	50.0	.00
217	147	149	500.0	16.0	52.0	.00
218	149	151	500.0	16.0	52.0	.00
219	150	151	400.0	12.0	49.0	.00
220	151	152	650.0	12.0	49.0	.00
221	151	153	2800.0	12.0	49.0	.00
222	154	155	400.0	12.0	86.0	.00
223	156	154	2400.0	16.0	110.0	.00
224	157	156	600.0	12.0	48.0	.00
225	157	158	600.0	12.0	93.0	.00
226	159	158	1700.0	12.0	49.0	.00
227	160	159	1300.0	12.0	95.0	.00
228	161	160	600.0	12.0	95.0	.00
229	161	156	1150.0	16.0	110.0	.00
230	162	161	1750.0	16.0	110.0	.00
231	162	160	2400.0	24.0	120.0	.00
232	163	159	550.0	12.0	49.0	.00
233	163	164	600.0	12.0	95.0	.00
234	165	163	1200.0	12.0	49.0	.00
235	166	162	1100.0	20.0	110.0	.00
236	166	221	2500.0	12.0	48.0	.00
237	167	166	1200.0	20.0	110.0	.00
238	168	167	1300.0	20.0	110.0	.00
239	168	169	4100.0	16.0	54.0	.00
240	169	170	5300.0	16.0	77.0	.00
241	160	157	1150.0	24.0	120.0	.00
242	171	165	6600.0	12.0	49.0	.00
243	170	171	1000.0	12.0	74.0	.00
244	170	172	200.0	16.0	76.0	.00
245	172	173	1300.0	12.0	74.0	.00
246	173	175	800.0	12.0	63.0	.00
247	173	174	100.0	12.0	63.0	.00
248	176	168	2000.0	20.0	110.0	.00
249	178	176	2200.0	30.0	93.0	.00
250	177	176	300.0	20.0	110.0	.00
251	180	177	2100.0	12.0	49.0	.00
252	179	178	300.0	36.0	110.0	.00
253	179	181	200.0	16.0	66.0	.00
254	180	179	450.0	36.0	110.0	.00
255	181	183	2400.0	12.0	79.0	.00
256	181	182	400.0	16.0	81.0	.00
257	182	183	2700.0	12.0	68.0	.00
258	183	184	1100.0	12.0	79.0	.00
259	184	185	500.0	12.0	79.0	.00
260	184	186	500.0	12.0	79.0	.00
261	180	182	300.0	12.0	49.0	.00
262	187	180	2450.0	12.0	61.0	.00
263	189	180	2600.0	36.0	110.0	.00
264	182	200	2700.0	12.0	49.0	.00
265	187	188	500.0	12.0	61.0	.00
266	189	187	300.0	12.0	81.0	.00
267	190	189	3300.0	36.0	110.0	.00
268	189	195	4700.0	44.0	110.0	.00
269	190	191	2700.0	16.0	60.0	.00
270	214	190	5800.0	16.0	60.0	.00
271	213	190	4000.0	36.0	110.0	.00
272	191	192	1400.0	12.0	51.0	.00

273	192	193	800.0	16.0	66.0	.00
274	194	193	400.0	16.0	66.0	.00
275	193	195	2300.0	12.0	63.0	.00
276	195	197	2700.0	12.0	75.0	.00
277	195	196	2800.0	44.0	110.0	.00
278	198	194	2600.0	20.0	110.0	.00
279	194	199	3600.0	16.0	66.0	.00
280	198	199	1100.0	16.0	84.0	.00
281	201	191	2000.0	12.0	130.0	.00
282	202	198	3800.0	20.0	110.0	.00
283	199	204	2800.0	16.0	66.0	.00
284	204	205	3200.0	12.0	90.0	.00
285	204	205	3200.0	12.0	66.0	.00
286	205	206	1800.0	12.0	66.0	.00
287	206	207	5000.0	12.0	66.0	.00
288	203	204	2500.0	16.0	66.0	.00
289	209	203	700.0	16.0	65.0	.00
290	208	202	600.0	24.0	110.0	.00
291	201	203	2400.0	12.0	52.0	.00
292	210	208	1550.0	20.0	110.0	.00
293	211	201	2800.0	12.0	75.0	.00
294	212	211	550.0	18.0	85.0	.00
295	213	210	1800.0	24.0	110.0	.00
296	214	212	1200.0	12.0	75.0	.00
297	218	213	2000.0	36.0	110.0	.00
298	27	218	1000.0	44.0	110.0	.00
299	27	214	1550.0	16.0	75.0	.00
300	209	208	450.0	24.0	110.0	.00
301	215	209	2200.0	18.0	89.0	.00
302	216	215	3850.0	16.0	65.0	.00
303	217	209	6100.0	24.0	110.0	.00
304	216	203	6350.0	12.0	51.0	.00
305	23	217	1000.0	30.0	110.0	.00
306	217	216	300.0	30.0	110.0	.00
307	142	219	1300.0	16.0	106.0	.00
308	220	132	800.0	12.0	86.0	.00
309	221	165	1800.0	12.0	78.0	.00
310	42	43	350.0	30.0	120.0	.00
311	222	43	200.0	30.0	110.0	.00

A SUCCESSFUL GEOMETRIC VERIFICATION HAS BEEN COMPLETED

JUNCTION NUMBER	DEMAND	ELEVATION	CONNECTING PIPES			
1	.00	40.00	1	2		
2	.00	40.00	2	3	4	
3	.00	.00	3			
4	.00	.00	4	5	6	
5	.00	309.00	6	7	10	11
6	.00	361.00	7	8	9	
7	.00	348.00	9	10	12	
8	.00	225.00	12	13	15	16
9	.84	180.00	11	14	34	
10	.88	140.00	14	15	17	
11	.00	296.00	13			
12	.00	111.00	17	18		
13	.31	190.00	18			
14	.00	239.00	16	19	20	
15	.00	214.00	19	21	22	
16	.25	155.00	21			
17	.00	187.00	22	23	24	
18	.25	262.00	20	25	27	
19	.00	285.00	27			
20	.19	217.00	25	26	28	
21	.13	155.00	26			
22	.00	220.00	5	24	29	
23	.25	252.00	28	31	305	
24	.00	221.00	29	30	31	32
25	.00	51.00	40			
26	.00	.00	30			
27	.00	303.00	23	298	299	
28	.50	233.00	34	35	37	

29	.00	271.00	33	35	36			
30	.00	234.00	36	38	42			
31	.52	201.00	37	39	40			
32	.38	213.00	38	39	41			
33	.00	270.00	42	43	44			
34	.52	245.00	41	43	45	47		
35	.00	249.00	45	46	48			
36	.00	209.00	48	49	50			
37	.00	209.00	47	50	51			
38	.00	323.00	44	52	53	54	59	
39	.00	303.00	46	52	53	55	56	
40	.00	273.00	55	57	58			
41	.38	251.00	57					
42	.00	256.00	49	56	58	60	310	
43	.00	266.00	60	105	127	129	310	311
44	.00	386.00	59					
45	.00	185.00	51	61	62	63		
46	.00	136.00	61	64	74			
47	.00	134.00	62	80	84			
48	.00	236.00	63	88	93			
49	.00	100.00	64	81				
50	.00	63.00	65					
51	.56	168.00	66	67	68	69		
52	.00	143.00	67					
53	.25	204.00	68	70	72			
54	.00	239.00	69	70	71	73		
55	.50	230.00	71					
56	.19	171.00	73	76	77	83		
57	.19	214.00	72	74	75			
58	.00	235.00	75	76	84			
59	.00	151.00	77	78	82			
60	.50	.00	78					
61	.25	118.00	79	82	85			
62	.72	131.00	79	80	83	86		
63	.25	122.00	85	87	89			
64	.72	136.00	86	87	88	92		
65	.00	128.00	89	90	91			
66	.00	125.00	90					
67	.00	135.00	91	94	95	97		
68	.00	137.00	94					
69	.00	162.00	92	95	96	98		
70	.00	215.00	93	96	99			
71	.00	224.00	99	100	104			
72	.94	165.00	98	100	101	103		
73	.47	161.00	97	101	102			
74	.00	224.00	104	105	106			
75	.50	169.00	103	108	112	121		
76	.34	172.00	102	108	109			
77	.50	176.00	112	113	114			
78	.00	224.00	106	107	115			
79	.00	224.00	114	115	116			
80	.00	224.00	116	117				
81	.00	205.00	113	118	120			
82	.00	184.00	109	110				
83	.00	192.00	110	111				
84	.00	220.00	111	118	119			
85	.31	245.00	117	122	123			
86	.00	206.00	107	121				
87	.00	270.00	122	124	125			
88	.50	258.00	124	130	131	132		
89	.00	262.00	123	125	126			
90	.00	268.00	126	127	128	130		
91	.00	274.00	128	129				
92	.00	190.00	132	133	134	135	136	
93	.50	172.00	131	135	136	137	138	139
94	.00	200.00	137	140				
95	.00	192.00	140	141				
96	.00	186.00	138	144	145			
97	.25	192.00	144					
98	.00	141.00	142	146	149			
99	.00	147.00	146	147	148			
100	.00	133.00	148	149	150			

101	.00	121.00	65	66	81	
102	.38	161.00	119	147	151	152
103	.50	130.00	120	141	142	143
104	.00	210.00	151			
105	.72	156.00	152	153	154	155
106	.00	134.00	150	153	156	157
107	.00	127.00	143	157	158	
108	.00	138.00	158	159	160	
109	.31	188.00	160	161	162	
110	.00	210.00	145	162	163	
111	.00	165.00	139	163	164	
112	.00	152.00	134	164	165	166
113	.00	144.00	165	167	200	
114	.56	148.00	167	168	169	
115	.00	120.00	168			
116	.47	105.00	161	169	170	
117	.00	102.00	159	170	171	
118	.00	114.00	171	172	173	
119	.00	120.00	172	174	175	
120	.00	148.00	156	175	176	177
121	.00	164.00	155	177	178	179
122	.00	194.00	179	180	181	
123	.00	242.00	181	182	184	
124	.88	222.00	182	183	185	
125	.00	190.00	154	180	183	
126	.00	90.00	185	186	187	
127	.88	185.00	184	186	188	189
128	.00	225.00	189	190	191	
129	.00	220.00	178	191	192	193
130	.00	191.00	193	194	195	196
131	.00	220.00	176	195	197	
132	2.25	198.00	197	199	308	
133	.00	170.00	196	199	201	202
134	.00	.00	173	174	198	
135	.00	150.00	201			
136	.00	100.00	202	203	204	
137	1.96	52.00	194	204	205	206
138	.00	180.00	192	206	207	208
139	.00	200.00	190	208	209	
140	.00	182.00	188	209	210	
141	.00	215.00	210			
142	3.32	233.00	211	212	307	
143	.00	91.00	211			
144	.00	270.00	212			
145	.00	335.00	213			
146	.00	260.00	207	213	214	
147	.00	210.00	205	214	215	217
148	.00	100.00	203	215	216	
149	.00	191.00	216	217	218	
150	.00	213.00	219			
151	2.13	171.00	218	219	220	221
152	.00	105.00	220			
153	.00	228.00	221			
154	.38	214.00	133	222	223	
155	.00	155.00	222			
156	.50	138.00	223	224	229	
157	.00	114.00	166	224	225	241
158	.00	84.00	200	225	226	
159	.00	120.00	226	227	232	
160	.38	162.00	227	228	231	241
161	.00	161.00	228	229	230	
162	.00	313.00	230	231	235	
163	.00	142.00	232	233	234	
164	.00	108.00	233			
165	.35	176.00	234	242	309	
166	.63	185.00	235	236	237	
167	.00	235.00	237	238		
168	.50	165.00	238	239	248	
169	.00	48.00	239	240		
170	.00	74.00	240	243	244	
171	.00	105.00	242	243		
172	.00	6.00	244	245		

173	.00	192.00	245	246	247		
174	.00	136.00	247				
175	1.11	300.00	246				
176	.50	135.00	248	249	250		
177	.00	157.00	250	251			
178	.00	129.00	249	252			
179	.00	165.00	252	253	254		
180	.00	202.00	251	254	261	262	263
181	.00	161.00	253	255	256		
182	.00	175.00	256	257	261	264	
183	.30	247.00	255	257	258		
184	.25	227.00	258	259	260		
185	.00	263.00	259				
186	.00	196.00	260				
187	.76	201.00	262	265	266		
188	.00	165.00	265				
189	13.30	185.00	263	266	267	268	
190	.25	165.00	267	269	270	271	
191	.00	171.00	269	272	281		
192	.00	148.00	272	273			
193	.00	174.00	273	274	275		
194	.00	220.00	274	278	279		
195	.63	225.00	268	275	276	277	
196	.00	131.00	277				
197	.35	215.00	276				
198	1.15	218.00	278	280	282		
199	.00	272.00	279	280	283		
200	.55	154.00	264				
201	.00	144.00	281	291	293		
202	.00	187.00	282	290			
203	1.13	205.00	288	289	291	304	
204	.00	240.00	283	284	285	288	
205	1.04	158.00	284	285	286		
206	.00	.00	286	287			
207	.00	76.00	287				
208	.00	186.00	290	292	300		
209	.00	195.00	289	300	301	303	
210	.00	213.00	292	295			
211	.00	198.00	293	294			
212	.00	.00	294	296			
213	.00	254.00	271	295	297		
214	.00	289.00	270	296	299		
215	.00	275.00	301	302			
216	.00	291.00	302	304	306		
217	.00	293.00	303	305	306		
218	.00	274.00	297	298			
219	.81	90.00	187	307			
220	.00	200.00	198	308			
221	.00	165.00	236	309			
222	.00	268.00	54	311			

OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD
20 VALUES ARE OUTPUT FOR MAXIMUM AND MINIMUM PRESSURES

THIS SYSTEM HAS 311 PIPES WITH 222 JUNCTIONS , 86 LOOPS AND 4 FGNS

Sunset Max Day Demand
Max Day = Ave Day x 1.5 Ave Day = 110.5 MGD for Entire System
Job# 9838.12 Date: 10/15/89

PIPE NO.	NODE NOS.		FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1	0	1	.53	.00	.00	.00	.04	.00
2	1	2	.53	.00	.00	.00	.04	.00
3	2	3	.00	.00	.00	.00	.00	.00
4	2	4	.53	.00	.00	.00	.04	.00
5	4	22	.14	1.03	.00	.00	.27	.19
6	4	5	.39	.00	.00	.00	.03	.00
7	5	6	-1.24	.00	.00	.00	-.10	.00

8	0	6	3.57	.00	.00	.00	.28	.01
9	6	7	2.33	.00	.00	.00	.23	.01
10	5	7	.08	.00	.00	.00	.09	.01
11	5	9	1.55	3.58	.00	.00	1.72	1.88
12	7	8	2.41	.02	.00	.00	.23	.01
13	8	11	.00	.00	.00	.00	.00	.00
14	9	10	.36	1.45	.00	.00	.71	.54
15	8	10	1.43	5.01	.00	.00	1.58	1.70
16	8	14	.99	.00	.00	.00	.10	.00
17	10	12	.47	.17	.00	.00	.41	.06
18	12	13	.47	1.59	.00	.00	.52	.26
19	14	15	.38	.00	.00	.00	.04	.00
20	14	18	.61	5.59	.00	.00	1.21	1.55
21	15	16	.38	1.49	.00	.00	.74	.60
THE CHECK VALVE IN LINE NUMBER 22 IS CLOSED								
23	17	27	25.84	5.96	.00	.00	3.79	1.30
24	22	17	25.84	1.29	.00	.00	2.51	.48
25	18	20	.24	.38	.00	.00	.47	.25
26	20	21	.19	.26	.00	.00	.38	.22
27	18	19	.00	.00	.00	.00	.00	.00
28	23	20	.24	2.12	.00	.00	.48	.36
29	24	22	25.70	.95	.00	.00	2.50	.47
30	24	26	.00	.00	.00	.00	.00	.00
31	24	23	8.39	3.80	.00	.00	2.64	1.04
32	0	24	34.09	.08	.00	.00	3.32	.80
33	0	29	41.41	1.44	.00	.00	3.26	.69
34	28	9	.07	.07	.00	.00	.14	.03
35	29	28	1.15	2.07	.00	.00	1.28	1.09
36	29	30	40.26	.91	.00	.00	3.17	.65
37	28	31	.33	.97	.00	.00	.65	.46
38	30	32	1.88	1.78	.00	.00	2.08	2.97
39	32	31	.45	.34	.00	.00	.50	.19
40	31	25	.00	.00	.00	.00	.00	.00
41	32	34	.86	.60	.00	.00	.95	.24
42	30	33	38.39	1.43	.00	.00	3.02	.60
43	33	34	10.06	.95	.00	.00	3.17	1.46
44	33	38	28.32	1.39	.00	.00	2.23	.34
45	34	35	1.36	.17	.00	.00	1.50	.56
46	35	39	.42	1.08	.00	.00	.46	.29
47	34	37	8.78	1.99	.00	.00	2.77	1.13
48	35	36	.94	1.82	.00	.00	1.04	1.30
49	42	36	-1.29	-.89	.00	.00	-.91	-.23
50	36	37	-.35	.00	.00	.00	-.11	.00
51	37	45	8.44	3.16	.00	.00	2.66	1.05
52	38	39	9.18	.80	.00	.00	2.89	1.23
53	38	39	5.11	.80	.00	.00	2.51	1.23
54	38	222	14.04	2.34	.00	.00	3.07	1.11
55	39	40	9.55	.86	.00	.00	3.01	1.32
56	39	42	5.15	1.63	.00	.00	2.54	1.25
57	40	41	.57	2.50	.00	.00	1.12	2.78
58	40	42	8.98	.77	.00	.00	2.83	1.18
59	38	44	.00	.00	.00	.00	.00	.00
60	42	43	5.21	.45	.00	.00	2.56	1.28
61	45	46	3.52	2.56	.00	.00	2.50	1.51
62	45	47	1.81	8.77	.00	.00	2.00	4.39
63	45	48	3.10	1.78	.00	.00	2.20	1.19
64	46	49	1.86	1.44	.00	.00	1.32	.46
65	101	50	.00	.00	.00	.00	.00	.00
66	101	51	1.86	2.30	.00	.00	2.07	3.54
67	51	52	.00	.00	.00	.00	.00	.00
68	51	53	.26	.61	.00	.00	.51	.41
69	51	54	.76	1.90	.00	.00	.85	.68
70	53	54	.49	1.28	.00	.00	.97	.99
71	54	55	.75	1.40	.00	.00	1.48	2.15
72	57	53	.61	2.94	.00	.00	1.20	1.96
73	54	56	.51	.48	.00	.00	.56	.32
74	46	57	1.66	3.71	.00	.00	1.84	2.85
75	57	58	.77	2.53	.00	.00	1.51	3.89
76	58	56	.81	2.17	.00	.00	1.59	3.34
77	56	59	.53	1.97	.00	.00	1.04	1.52
78	59	60	.75	1.45	.00	.00	1.48	2.90
79	62	61	.69	1.10	.00	.00	.77	.84

80	47	62	1.77	2.73	.00	.00	1.96	4.20
81	49	101	1.86	2.30	.00	.00	2.07	3.54
82	61	59	.22	.35	.00	.00	.44	.20
83	56	62	.50	.53	.00	.00	.56	.31
84	47	58	.04	.03	.00	.00	.08	.02
85	61	63	.09	.14	.00	.00	.19	.10
86	62	64	.50	.46	.00	.00	.55	.31
87	64	63	.39	.78	.00	.00	.76	.60
88	48	64	1.04	10.18	.00	.00	2.05	3.77
89	63	65	.11	.05	.00	.00	.21	.05
90	65	66	.00	.00	.00	.00	.00	.00
91	65	67	.11	.03	.00	.00	.21	.05
92	64	69	.07	.02	.00	.00	.08	.01
93	48	70	2.06	.84	.00	.00	1.46	.56
94	67	68	.00	.00	.00	.00	.00	.00
95	69	67	.45	.84	.00	.00	.88	.65
96	70	69	1.10	9.36	.00	.00	2.17	3.47
97	67	73	.55	1.93	.00	.00	1.09	1.13
98	69	72	.73	1.13	.00	.00	.81	.90
99	70	71	.96	.17	.00	.00	.68	.14
100	71	72	1.08	10.32	.00	.00	2.12	3.82
101	72	73	.59	1.64	.00	.00	1.17	1.26
102	73	76	.44	1.16	.00	.00	.87	.75
103	72	75	-.20	-.13	.00	.00	-.22	-.08
104	71	74	-.12	.00	.00	.00	-.09	.00
105	43	74	10.74	4.61	.00	.00	3.38	1.65
106	74	78	10.62	.97	.00	.00	3.35	1.61
107	78	86	9.58	.53	.00	.00	3.02	1.33
108	75	76	6.43	2.93	.00	.00	3.17	1.89
109	76	82	6.36	1.11	.00	.00	3.13	1.85
110	82	83	6.36	.92	.00	.00	3.27	2.05
111	83	84	6.36	4.05	.00	.00	4.51	4.50
112	75	77	2.20	2.54	.00	.00	2.44	7.24
113	77	81	2.01	6.48	.00	.00	2.22	4.05
114	79	77	.55	6.52	.00	.00	1.08	2.51
115	78	79	1.04	5.24	.00	.00	2.04	8.74
116	79	80	.49	1.40	.00	.00	.96	2.15
117	80	85	.49	1.16	.00	.00	.54	.47
118	81	84	.00	.00	.00	.00	-.01	.00
119	84	102	6.36	20.46	.00	.00	4.51	4.50
120	81	103	2.01	19.89	.00	.00	2.23	4.06
121	86	75	9.58	8.70	.00	.00	4.72	3.95
122	85	87	1.18	.67	.00	.00	1.30	.59
123	89	85	1.16	3.17	.00	.00	1.28	2.27
124	87	88	10.15	3.02	.00	.00	5.95	6.72
125	89	87	8.97	3.85	.00	.00	4.42	3.50
126	90	89	10.13	2.01	.00	.00	5.94	6.69
127	43	90	7.34	8.20	.00	.00	3.61	2.41
128	91	90	11.38	3.80	.00	.00	5.60	5.43
129	43	91	11.38	4.40	.00	.00	3.59	1.83
130	90	88	8.59	8.88	.00	.00	5.03	4.93
131	88	93	9.65	18.83	.00	.00	4.75	4.01
132	88	92	8.34	18.66	.00	.00	4.89	4.66
133	92	154	1.26	.74	.00	.00	1.40	.67
134	92	112	5.35	.92	.00	.00	3.14	2.05
135	92	93	.13	.17	.00	.00	.25	.22
136	92	93	1.59	.17	.00	.00	.93	.22
137	93	94	4.03	1.94	.00	.00	2.36	1.21
138	93	96	.59	3.77	.00	.00	1.16	3.59
139	93	111	6.01	.83	.00	.00	2.96	1.66
140	94	95	4.03	3.55	.00	.00	2.86	5.92
141	95	103	4.03	2.30	.00	.00	2.36	1.21
142	103	98	3.03	.46	.00	.00	1.77	.71
143	103	107	2.26	2.52	.00	.00	2.50	5.04
144	96	97	.38	1.56	.00	.00	.74	1.56
145	96	110	.21	.21	.00	.00	.42	.42
146	98	99	1.56	.07	.00	.00	.91	.21
147	99	102	1.00	.03	.00	.00	.59	.09
148	99	100	.56	3.22	.00	.00	1.10	2.48
149	98	100	1.47	3.29	.00	.00	1.63	3.29
150	100	106	2.03	2.99	.00	.00	2.24	5.98
151	102	104	.00	.00	.00	.00	.00	.00

152	102	105	6.79	7.36	.00	.00	4.82	5.08
153	106	105	6.31	1.18	.00	.00	3.11	1.82
154	105	125	8.63	2.12	.00	.00	4.25	3.25
155	105	121	3.39	6.19	.00	.00	3.76	12.38
156	106	120	3.43	7.94	.00	.00	3.80	15.89
157	107	106	7.71	4.23	.00	.00	3.80	2.64
158	108	107	5.46	1.81	.00	.00	2.69	1.39
159	108	117	1.80	1.86	.00	.00	1.99	1.28
160	109	108	7.25	2.48	.00	.00	3.57	2.36
161	109	116	.75	1.39	.00	.00	.83	.96
162	110	109	8.47	2.04	.00	.00	4.17	3.15
163	111	110	8.26	3.15	.00	.00	4.07	3.00
164	112	111	2.25	.08	.00	.00	1.11	.27
165	112	113	1.96	.29	.00	.00	1.15	.32
166	157	112	-1.14	-.29	.00	.00	-.56	-.08
167	113	114	1.89	.16	.00	.00	1.11	.30
168	114	115	.00	.00	.00	.00	.00	.00
169	114	116	1.05	6.21	.00	.00	1.16	2.59
170	116	117	1.10	2.95	.00	.00	1.22	2.81
171	117	118	2.90	11.85	.00	.00	3.21	16.93
172	118	119	.68	.75	.00	.00	.75	1.16
173	118	134	2.21	7.80	.00	.00	4.36	7.80
174	119	134	1.22	7.04	.00	.00	2.40	3.91
175	119	120	-.54	-.49	.00	.00	-.59	-.75
176	120	131	3.48	41.96	.00	.00	3.86	17.48
177	121	120	.59	.57	.00	.00	.65	.88
178	121	129	3.94	47.50	.00	.00	4.37	16.38
179	122	121	1.14	1.95	.00	.00	1.26	3.01
180	125	122	1.68	2.12	.00	.00	1.86	4.24
181	122	123	.54	.77	.00	.00	.60	.77
182	124	123	.93	.71	.00	.00	1.03	1.42
183	125	124	6.95	2.18	.00	.00	3.42	2.18
184	123	127	1.48	62.47	.00	.00	2.91	21.54
185	124	126	4.69	71.37	.00	.00	5.20	16.22
186	126	127	-1.50	-8.19	.00	.00	-2.96	-8.19
187	126	219	6.20	34.40	.00	.00	6.86	24.57
188	127	140	-.40	-2.67	.00	.00	-.79	-1.91
189	127	128	-.95	-8.27	.00	.00	-1.86	-6.36
190	128	139	.60	3.80	.00	.00	1.18	2.72
191	129	128	1.54	5.51	.00	.00	3.04	15.75
192	129	138	2.16	9.45	.00	.00	2.40	6.75
193	129	130	.24	.34	.00	.00	.46	.48
194	130	137	2.47	12.96	.00	.00	2.74	9.26
195	131	130	2.66	5.31	.00	.00	2.95	10.62
196	130	133	.43	1.95	.00	.00	.84	1.44
197	131	132	.82	4.90	.00	.00	1.62	4.90
198	134	220	3.43	17.55	.00	.00	6.76	17.55
199	133	132	-.88	-2.36	.00	.00	-1.73	-2.62
200	158	113	-.07	-.02	.00	.00	-.08	-.01
201	133	135	.00	.00	.00	.00	.00	.00
202	133	136	1.30	7.61	.00	.00	2.57	5.44
203	136	148	.75	4.48	.00	.00	1.48	4.48
204	136	137	.55	3.40	.00	.00	1.09	2.52
205	137	147	.89	1.40	.00	.00	.99	1.40
206	138	137	.81	3.85	.00	.00	1.60	5.13
207	138	146	1.55	2.52	.00	.00	1.72	2.52
208	139	138	.20	.13	.00	.00	.39	.38
209	140	139	-.40	-1.79	.00	.00	-.79	-1.38
210	140	141	.00	.00	.00	.00	.00	.00
211	142	143	.00	.00	.00	.00	.00	.00
212	142	144	.00	.00	.00	.00	.00	.00
213	146	145	.00	.00	.00	.00	.00	.00
214	146	147	1.55	2.74	.00	.00	1.72	3.65
215	147	148	-.15	-.32	.00	.00	-.31	-.24
216	148	149	.60	5.40	.00	.00	1.18	2.92
217	147	149	2.60	5.08	.00	.00	2.88	10.16
218	149	151	3.20	7.46	.00	.00	3.54	14.92
219	150	151	.00	.00	.00	.00	.00	.00
220	151	152	.00	.00	.00	.00	.00	.00
221	151	153	.00	.00	.00	.00	.00	.00
222	154	155	.00	.00	.00	.00	.00	.00
223	156	154	-.69	-.53	.00	.00	-.77	-.22

224	157	156	.09	.05	.00	.00	.17	.09
225	157	158	.10	.02	.00	.00	.20	.03
226	159	158	-.17	-.51	.00	.00	-.34	-.30
227	160	159	.37	.48	.00	.00	.73	.37
228	161	160	.01	.00	.00	.00	.02	.00
229	161	156	-.03	.00	.00	.00	-.03	.00
230	162	161	-.02	.00	.00	.00	-.02	.00
231	162	160	-.03	.00	.00	.00	-.01	.00
232	163	159	-.54	-1.39	.00	.00	-1.07	-2.53
233	163	164	.00	.00	.00	.00	.00	.00
234	165	163	-.54	-3.03	.00	.00	-1.07	-2.53
235	166	162	-.05	.00	.00	.00	-.03	.00
236	166	221	.40	3.79	.00	.00	.79	1.52
237	167	166	1.30	.29	.00	.00	.92	.24
238	168	167	1.30	.31	.00	.00	.92	.24
239	168	169	1.25	9.96	.00	.00	1.38	2.43
240	169	170	1.25	6.67	.00	.00	1.38	1.26
241	160	157	-.96	-.05	.00	.00	-.47	-.05
242	171	165	-.42	-10.40	.00	.00	-.83	-1.58
243	170	171	-.42	-.73	.00	.00	-.83	-.73
244	170	172	1.66	.44	.00	.00	1.84	2.21
245	172	173	1.66	12.25	.00	.00	3.28	9.42
246	173	175	1.66	10.15	.00	.00	3.28	12.69
247	173	174	.00	.00	.00	.00	.00	.00
248	176	168	3.30	2.66	.00	.00	2.34	1.33
249	178	176	3.85	.74	.00	.00	1.21	.34
250	177	176	.20	.00	.00	.00	.14	.01
251	180	177	.20	.84	.00	.00	.39	.40
252	179	178	3.85	.03	.00	.00	.84	.10
253	179	181	1.19	.31	.00	.00	1.32	1.55
254	180	179	5.04	.08	.00	.00	1.10	.17
255	181	183	.47	1.90	.00	.00	.92	.79
256	181	182	.73	.17	.00	.00	.80	.42
257	182	183	.36	1.73	.00	.00	.71	.64
258	183	184	.38	.58	.00	.00	.74	.53
259	184	185	.00	.00	.00	.00	.00	.00
260	184	186	.00	.00	.00	.00	.00	.00
261	180	182	.46	.55	.00	.00	.90	1.84
262	187	180	-.14	-.35	.00	.00	-.28	-.14
263	189	180	5.84	.57	.00	.00	1.28	.22
264	182	200	.83	14.87	.00	.00	1.63	5.51
265	187	188	.00	.00	.00	.00	.00	.00
266	189	187	1.00	.92	.00	.00	1.96	3.08
267	190	189	26.99	12.32	.00	.00	5.91	3.73
268	189	195	.20	.00	.00	.00	.03	.00
269	190	191	-1.16	-4.76	.00	.00	-1.29	-1.76
270	214	190	1.40	14.44	.00	.00	1.55	2.49
271	213	190	24.80	12.77	.00	.00	5.43	3.19
272	191	192	-.18	-.45	.00	.00	-.36	-.32
273	192	193	-.18	-.04	.00	.00	-.20	-.05
274	194	193	1.45	.89	.00	.00	1.61	2.22
275	193	195	1.27	17.57	.00	.00	2.49	7.64
276	195	197	.52	2.93	.00	.00	1.03	1.08
277	195	196	.00	.00	.00	.00	.00	.00
278	198	194	1.25	.57	.00	.00	.88	.22
279	194	199	-.20	-.21	.00	.00	-.23	-.06
280	198	199	.66	.36	.00	.00	.73	.33
281	201	191	.98	2.48	.00	.00	1.93	1.24
282	202	198	3.63	6.04	.00	.00	2.57	1.59
283	199	204	.45	.72	.00	.00	.50	.26
284	204	205	.90	6.71	.00	.00	1.77	2.10
285	204	205	.66	6.71	.00	.00	1.30	2.10
286	205	206	.00	.00	.00	.00	.00	.00
287	206	207	.00	.00	.00	.00	.00	.00
288	203	204	1.11	3.37	.00	.00	1.23	1.35
289	209	203	2.57	4.61	.00	.00	2.85	6.58
290	208	202	3.63	.39	.00	.00	1.79	.65
291	201	203	-.29	-1.76	.00	.00	-.58	-.73
292	210	208	-1.05	-.25	.00	.00	-.74	-.16
293	211	201	.68	4.97	.00	.00	1.35	1.77
294	212	211	.68	.11	.00	.00	.60	.20
295	213	210	-1.05	-.12	.00	.00	-.52	-.07

296	214	212	.68	2.13	.00	.00	1.35	1.77
297	218	213	23.75	5.90	.00	.00	5.20	2.95
298	27	218	23.75	1.11	.00	.00	3.48	1.11
299	27	214	2.09	5.33	.00	.00	2.31	3.44
300	209	208	4.67	.47	.00	.00	2.30	1.05
301	215	209	1.39	1.47	.00	.00	1.22	.67
302	216	215	1.39	8.17	.00	.00	1.54	2.12
303	217	209	5.85	9.66	.00	.00	2.88	1.58
304	216	203	.53	14.25	.00	.00	1.04	2.24
305	23	217	7.77	.90	.00	.00	2.45	.90
306	217	216	1.92	.02	.00	.00	.61	.07
307	142	219	-4.98	-11.80	.00	.00	-5.52	-9.07
308	220	132	3.43	21.78	.00	.00	6.76	27.23
309	221	165	.40	1.11	.00	.00	.79	.62
310	42	43	10.21	.45	.00	.00	3.22	1.28
311	222	43	14.04	.54	.00	.00	4.42	2.70

JUNCTION NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
1	.00	385.00	40.00	149.50
2	.00	385.00	40.00	149.50
3	.00	385.00		
4	.00	385.00		
5	.00	385.00	309.00	32.93
6	.00	385.00	361.00	10.40
7	.00	385.00	348.00	16.03
8	.00	384.97	225.00	69.32
9	1.26	381.42	180.00	87.28
10	1.32	379.97	140.00	103.98
11	.00	384.97	296.00	38.56
12	.00	379.80	111.00	116.48
13	.47	378.21	190.00	81.56
14	.00	384.97	239.00	63.25
15	.00	384.97	214.00	74.09
16	.38	383.48	155.00	99.01
17	.00	382.68	187.00	84.80
18	.38	379.38	262.00	50.86
19	.00	379.38	285.00	40.90
20	.28	379.00	217.00	70.20
21	.19	378.73	155.00	96.95
22	.00	383.97	220.00	71.05
23	.38	381.12	252.00	55.95
24	.00	384.92	221.00	71.03
25	.00	380.52	51.00	142.79
26	.00	384.92		
27	.00	376.72	303.00	31.94
28	.75	381.49	233.00	64.35
29	.00	383.56	271.00	48.78
30	.00	382.65	234.00	64.41
31	.78	380.52	201.00	77.79
32	.57	380.87	213.00	72.74
33	.00	381.22	270.00	48.19
34	.78	380.27	245.00	58.62
35	.00	380.10	249.00	56.81
36	.00	378.28	209.00	73.36
37	.00	378.28	209.00	73.36
38	.00	379.83	323.00	24.63
39	.00	379.03	303.00	32.94
40	.00	378.17	273.00	45.57
41	.57	375.67	251.00	54.02
42	.00	377.40	256.00	52.61
43	.00	376.[illegible]5	266.00	48.08
44	.00	379.[illegible]	386.00	-2.67
45	.00	375.13	185.00	82.39
46	.00	372.56	136.00	102.51
47	.00	366.35	134.00	100.69
48	.00	373.34	236.00	59.51
49	.00	371.13	100.00	117.49
50	.00	368.83	63.00	132.53
51	.84	366.53	168.00	86.03
52	.00	366.53	143.00	96.86
53	.38	365.91	204.00	70.16

54	.00	364.63	239.00	54.44
55	.75	363.23	230.00	57.73
56	.28	364.15	171.00	83.70
57	.28	368.85	214.00	67.10
58	.00	366.32	235.00	56.91
59	.00	362.18	151.00	91.51
60	.75	360.73		
61	.38	362.53	118.00	105.96
62	1.08	363.62	131.00	100.80
63	.38	362.38	122.00	104.17
64	1.08	363.16	136.00	98.44
65	.00	362.33	128.00	101.54
66	.00	362.33	125.00	102.84
67	.00	362.30	135.00	98.50
68	.00	362.30	137.00	97.63
69	.00	363.14	162.00	87.16
70	.00	372.50	215.00	68.25
71	.00	372.34	224.00	64.28
72	1.41	362.02	165.00	85.37
73	.71	360.37	161.00	86.39
74	.00	372.34	224.00	64.28
75	.75	362.14	169.00	83.69
76	.51	359.21	172.00	81.13
77	.75	359.61	176.00	79.56
78	.00	371.37	224.00	63.86
79	.00	366.13	224.00	61.59
80	.00	364.73	224.00	60.98
81	.00	353.13	205.00	64.19
82	.00	358.10	184.00	75.44
83	.00	357.18	192.00	71.58
84	.00	353.13	220.00	57.69
85	.47	363.57	245.00	51.38
86	.00	370.84	206.00	71.43
87	.00	362.89	270.00	40.25
88	.75	359.87	258.00	44.14
89	.00	366.74	262.00	45.39
90	.00	368.75	268.00	43.66
91	.00	372.55	274.00	42.71
92	.00	341.21	190.00	65.52
93	.75	341.04	172.00	73.25
94	.00	339.10	200.00	60.28
95	.00	335.54	192.00	62.20
96	.00	337.26	186.00	65.55
97	.38	335.70	192.00	62.27
98	.00	332.78	141.00	83.10
99	.00	332.70	147.00	80.47
100	.00	329.48	133.00	85.14
101	.00	368.83	121.00	107.39
102	.57	332.67	161.00	74.39
103	.75	333.24	130.00	88.07
104	.00	332.67	210.00	53.16
105	1.08	325.31	156.00	73.37
106	.00	326.49	134.00	83.41
107	.00	330.72	127.00	88.28
108	.00	332.53	138.00	84.30
109	.47	335.01	188.00	63.70
110	.00	337.05	210.00	55.06
111	.00	340.21	165.00	75.92
112	.00	340.29	152.00	81.59
113	.00	340.00	144.00	84.93
114	.84	339.83	148.00	83.13
115	.00	339.83	120.00	95.26
116	.71	333.62	105.00	99.07
117	.00	330.67	102.00	99.09
118	.00	318.82	114.00	88.75
119	.00	318.06	120.00	85.83
120	.00	318.55	148.00	73.90
121	.00	319.12	164.00	67.22
122	.00	321.07	194.00	55.06
123	.00	320.31	242.00	33.93
124	1.32	321.02	222.00	42.91
125	.00	323.19	190.00	57.72

126	.00	249.65	90.00	69.18
127	1.32	257.84	185.00	31.56
128	.00	266.11	225.00	17.81
129	.00	271.62	220.00	22.37
130	.00	271.28	191.00	34.79
131	.00	276.59	220.00	24.52
132	3.38	271.69	198.00	31.93
133	.00	269.33	170.00	43.04
134	.00	311.02		
135	.00	269.33	150.00	51.71
136	.00	261.72	100.00	70.08
137	2.94	258.32	52.00	89.41
138	.00	262.17	180.00	35.61
139	.00	262.30	200.00	27.00
140	.00	260.51	182.00	34.02
141	.00	260.51	215.00	19.72
142	4.98	203.45	233.00	-12.81
143	.00	203.45	91.00	48.73
144	.00	203.45	270.00	-28.84
145	.00	259.66	335.00	-32.65
146	.00	259.66	260.00	-.15
147	.00	256.92	210.00	20.33
148	.00	257.24	100.00	68.14
149	.00	251.84	191.00	26.36
150	.00	244.38	213.00	13.60
151	3.20	244.38	171.00	31.80
152	.00	244.38	105.00	60.40
153	.00	244.38	228.00	7.10
154	.57	340.48	214.00	54.81
155	.00	340.48	155.00	80.37
156	.75	339.95	138.00	87.51
157	.00	340.00	114.00	97.93
158	.00	339.98	84.00	110.92
159	.00	339.47	120.00	95.10
160	.57	339.95	162.00	77.11
161	.00	339.95	161.00	77.54
162	.00	339.95	313.00	11.68
163	.00	338.08	142.00	84.97
164	.00	338.08	108.00	99.70
165	.52	335.04	176.00	68.92
166	.94	339.95	185.00	67.14
167	.00	340.23	235.00	45.60
168	.75	340.54	165.00	76.07
169	.00	330.58	48.00	122.45
170	.00	323.91	74.00	108.29
171	.00	324.64	105.00	95.18
172	.00	323.47	6.00	137.57
173	.00	311.22	192.00	51.66
174	.00	311.22	136.00	75.93
175	1.66	301.07	300.00	.46
176	.75	343.20	135.00	90.22
177	.00	343.21	157.00	80.69
178	.00	343.94	129.00	93.14
179	.00	343.97	165.00	77.55
180	.00	344.05	202.00	61.55
181	.00	343.66	161.00	79.15
182	.00	343.49	175.00	73.01
183	.45	341.76	247.00	41.06
184	.38	341.18	227.00	49.48
185	.00	341.18	263.00	33.88
186	.00	341.18	196.00	62.91
187	1.14	343.69	201.00	61.83
188	.00	343.69	165.00	77.43
189	19.95	344.62	185.00	69.17
190	.38	356.94	165.00	83.17
191	.00	361.70	171.00	82.64
192	.00	362.15	148.00	92.80
193	.00	362.19	174.00	81.55
194	.00	363.07	220.00	62.00
195	.94	344.62	225.00	51.83
196	.00	344.62	131.00	92.57
197	.52	341.69	215.00	54.90

198	1.73	363.65	218.00	63.11
199	.00	363.29	272.00	39.56
200	.83	328.63	154.00	75.67
201	.00	364.18	144.00	95.41
202	.00	369.69	187.00	79.16
203	1.70	365.94	205.00	69.74
204	.00	362.57	240.00	53.11
205	1.56	355.85	158.00	85.74
206	.00	355.85		
207	.00	355.85	76.00	121.27
208	.00	370.08	186.00	79.77
209	.00	370.55	195.00	76.07
210	.00	369.83	213.00	67.96
211	.00	369.15	198.00	74.16
212	.00	369.26		
213	.00	369.71	254.00	50.14
214	.00	371.38	289.00	35.70
215	.00	372.02	275.00	42.04
216	.00	380.19	291.00	38.65
217	.00	380.21	293.00	37.79
218	.00	375.61	274.00	44.03
219	1.22	215.24	90.00	54.27
220	.00	293.47	200.00	40.50
221	.00	336.15	165.00	74.17
222	.00	377.49	268.00	47.45

MAXIMUM PRESSURES

1	.00	385.00	40.00	149.50
2	.00	385.00	40.00	149.50
25	.00	380.52	51.00	142.79
172	.00	323.47	6.00	137.57
50	.00	368.83	63.00	132.53
169	.00	330.58	48.00	122.45
207	.00	355.85	76.00	121.27
49	.00	371.13	100.00	117.49
12	.00	379.80	111.00	116.48
158	.00	339.98	84.00	110.92
170	.00	323.91	74.00	108.29
101	.00	368.83	121.00	107.39
61	.38	362.53	118.00	105.96
63	.38	362.38	122.00	104.17
10	1.32	379.97	140.00	103.98
66	.00	362.33	125.00	102.84
46	.00	372.56	136.00	102.51
65	.00	362.33	128.00	101.54
62	1.08	363.62	131.00	100.80
47	.00	366.35	134.00	100.69

MINIMUM PRESSURES

145	.00	259.66	335.00	-32.65
144	.00	203.45	270.00	-28.84
142	4.98	203.45	233.00	-12.81
44	.00	379.83	386.00	-2.67
146	.00	259.66	260.00	-.15
175	1.66	301.07	300.00	.46
153	.00	244.38	228.00	7.10
6	.00	385.00	361.00	10.40
162	.00	339.95	313.00	11.68
150	.00	244.38	213.00	13.60
7	.00	385.00	348.00	16.03
128	.00	266.11	225.00	17.81
141	.00	260.51	215.00	19.72
147	.00	256.92	210.00	20.33
129	.00	271.62	220.00	22.37
131	.00	276.59	220.00	24.52
38	.00	379.83	323.00	24.63
149	.00	251.84	191.00	26.36
139	.00	262.30	200.00	27.00
127	1.32	257.84	185.00	31.56

THE NET SYSTEM DEMAND = 79.60

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1	.53
8	3.57
32	34.09
33	41.41

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 79.61
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = .00

COLLEGE HILL PRESSURE ZONE - MAXIMUM DAY DEMAND

FLOWRATE IS EXPRESSED IN CFS AND PRESSURE IN PSIG

A SUMMARY OF THE ORIGINAL DATA FOLLOWS

PIPE NO.	NODE NOS.	LENGTH (FEET)	DIAMETER (INCHES)	ROUGHNESS	MINOR LOSS K	FIXED GRADE
1101	1202 1100	900.0	16.0	110.0	.00	
1102	1100 1102	1275.0	16.0	110.0	.00	
1103	1102 1103	600.0	16.0	110.0	.00	
1104	1102 1104	2850.0	12.0	100.0	.00	
1105	1103 1105	3450.0	12.0	85.0	.00	
1106	1103 1104	2850.0	12.0	115.0	.00	
1107	1100 1101	1350.0	12.0	85.0	.00	
1108	1104 1106	1950.0	12.0	85.0	.00	
1109	1106 1107	1650.0	12.0	95.0	.00	
1110	0 1201	400.0	20.0	110.0	.00	255.00
THERE IS A CHECK VALVE IN LINE NUMBER 1110						
1111	1114 1115	1500.0	6.0	90.0	.00	
1112	1112 1113	3000.0	16.0	110.0	.00	
1113	1112 1116	700.0	8.0	95.0	.00	
1114	1107 1116	2400.0	8.0	95.0	.00	
1115	1111 1112	2400.0	16.0	110.0	.00	
1116	1110 1111	1400.0	20.0	110.0	.00	
1117	1109 1110	400.0	20.0	110.0	.00	
1118	1109 1117	3000.0	20.0	110.0	.00	
1119	0 1108	240.0	30.0	110.0	.00	255.00
THERE IS A CHECK VALVE IN LINE NUMBER 1119						
1120	1108 1200	160.0	30.0	110.0	.00	
1121	1107 1115	5000.0	8.0	95.0	.00	
1122	1113 1114	700.0	16.0	110.0	.00	
1123	1117 1108	500.0	20.0	110.0	.00	
LINE 1123 IS CLOSED						
1124	0 1109	450.0	16.0	110.0	.00	295.00
THERE IS A CHECK VALVE IN LINE NUMBER 1124						
1201	1200 1204	675.0	36.0	110.0	.00	
1202	1204 1205	50.0	36.0	110.0	.00	
1203	1204 1206	300.0	22.0	110.0	.00	
1204	1200 1207	2400.0	24.0	110.0	.00	
1205	1206 1203	750.0	22.0	110.0	.00	
1206	1201 1203	450.0	22.0	110.0	.00	
1207	1202 1203	3400.0	16.0	110.0	.00	
1208	1205 1218	6750.0	36.0	110.0	.00	
1209	1243 1219	4520.0	24.0	110.0	.00	
1210	1206 1208	3000.0	22.0	110.0	.00	
1211	1244 1216	2040.0	24.0	110.0	.00	
1212	1207 1209	2625.0	24.0	110.0	.00	
1213	1209 1210	900.0	24.0	110.0	.00	
1214	1208 1209	2400.0	16.0	110.0	.00	
1215	1210 1246	1200.0	16.0	110.0	.00	
1216	1212 1213	1800.0	12.0	65.0	.00	
1217	1211 1212	100.0	12.0	65.0	.00	
1218	1211 1214	1950.0	12.0	65.0	.00	
1219	1208 1215	750.0	22.0	110.0	.00	
1220	1249 1232	4080.0	16.0	110.0	.00	
1221	1215 1216	50.0	24.0	110.0	.00	
1222	1215 1220	2550.0	22.0	110.0	.00	
1223	1218 1217	525.0	16.0	110.0	.00	
1224	1218 1219	750.0	16.0	110.0	.00	
1225	1219 1220	50.0	16.0	110.0	.00	
1226	1211 1231	4200.0	12.0	45.0	.00	

1227	1223	1227	1050.0	12.0	45.0	.00
1228	1217	1228	1875.0	24.0	110.0	.00
1229	1218	1224	1800.0	30.0	110.0	.00
1230	1219	1225	20.0	24.0	110.0	.00
1231	1222	1221	1650.0	12.0	105.0	.00
1232	1224	1222	2400.0	20.0	110.0	.00
1233	1224	1225	750.0	20.0	110.0	.00
1234	1225	1231	100.0	20.0	110.0	.00
1235	1222	1226	600.0	12.0	115.0	.00
1236	1227	1226	1800.0	12.0	55.0	.00
1237	1232	1227	1350.0	12.0	55.0	.00
1238	1229	1228	525.0	16.0	110.0	.00
1239	1230	1229	750.0	16.0	110.0	.00
1240	1230	1231	300.0	16.0	110.0	.00
1241	1229	1235	1900.0	20.0	110.0	.00
1242	1226	1237	3300.0	12.0	105.0	.00
1243	1224	1229	80.0	20.0	110.0	.00
1244	1232	1234	1600.0	16.0	110.0	.00
1245	1230	1239	2700.0	22.0	110.0	.00
1246	1233	1234	600.0	16.0	110.0	.00
1247	1235	1236	750.0	24.0	110.0	.00
1248	1233	1235	100.0	20.0	110.0	.00
1249	1233	1237	500.0	20.0	110.0	.00
1250	1234	1238	300.0	16.0	110.0	.00
1251	1225	1230	180.0	24.0	110.0	.00
1252	1243	1241	1400.0	8.0	100.0	.00
1253	1205	1243	2080.0	24.0	110.0	.00
1254	1241	1242	1120.0	8.0	100.0	.00
1255	1242	1208	1680.0	8.0	100.0	.00
1256	1207	1244	320.0	24.0	110.0	.00
1257	1216	1249	880.0	24.0	110.0	.00
1258	1246	1245	720.0	8.0	45.0	.00
1259	1245	1240	3900.0	6.0	40.0	.00
1260	1249	1248	3800.0	8.0	40.0	.00
1261	1246	1248	2300.0	16.0	110.0	.00
1262	1245	1247	2000.0	6.0	40.0	.00
1263	1248	1247	1500.0	8.0	45.0	.00
1264	1248	1212	2600.0	16.0	110.0	.00
1265	1205	1241	1720.0	8.0	100.0	.00
1266	1243	1244	640.0	16.0	110.0	.00
1301	1301	1302	450.0	12.0	55.0	.00
1302	1302	1303	450.0	12.0	55.0	.00
1303	1303	1304	400.0	16.0	110.0	.00
1304	1237	1304	50.0	16.0	110.0	.00
1305	1236	1304	100.0	24.0	110.0	.00
1306	1304	1305	750.0	16.0	110.0	.00
1307	1238	1305	600.0	16.0	110.0	.00
1308	1239	1323	1050.0	16.0	110.0	.00
1309	1302	1309	2850.0	12.0	55.0	.00
1310	1303	1310	2400.0	16.0	110.0	.00
1311	1304	1306	750.0	20.0	110.0	.00
1312	1306	1307	1050.0	12.0	55.0	.00
1313	1305	1307	450.0	16.0	110.0	.00
1314	1307	1313	300.0	16.0	110.0	.00
1315	1313	1323	750.0	16.0	110.0	.00
1316	1313	1314	300.0	16.0	110.0	.00
1317	1323	1322	600.0	16.0	110.0	.00
1318	1325	1324	750.0	12.0	45.0	.00
1319	1324	1326	525.0	12.0	45.0	.00
1320	1314	1315	250.0	16.0	110.0	.00
1321	1315	1322	300.0	16.0	110.0	.00
1322	1321	1322	450.0	22.0	110.0	.00
1323	1321	1324	225.0	12.0	45.0	.00
1324	1315	1316	450.0	16.0	110.0	.00
1325	1316	1321	300.0	12.0	45.0	.00
1326	1320	1321	1275.0	22.0	110.0	.00
1327	1319	1320	450.0	16.0	110.0	.00
1328	1316	1317	1200.0	16.0	110.0	.00
1329	1317	1319	300.0	16.0	110.0	.00
1330	1309	1308	450.0	12.0	55.0	.00
1331	1310	1309	750.0	12.0	55.0	.00
1332	1311	1310	450.0	12.0	55.0	.00

1333	1306	1311	1650.0	20.0	110.0	.00
1334	1311	1312	1350.0	12.0	70.0	.00
1335	1314	1312	1350.0	16.0	110.0	.00
1336	1318	1312	1425.0	12.0	45.0	.00
1337	1317	1318	400.0	16.0	110.0	.00
1338	1327	1350	500.0	16.0	110.0	.00
1339	1310	1328	1500.0	12.0	65.0	.00
1340	1311	1329	1500.0	20.0	110.0	.00
1341	1328	1329	450.0	16.0	110.0	.00
1342	1329	1330	1350.0	16.0	110.0	.00
1343	1312	1330	1500.0	16.0	110.0	.00
1344	1330	1331	1425.0	16.0	110.0	.00
1345	1318	1331	1500.0	16.0	110.0	.00
1346	1331	1332	1950.0	12.0	50.0	.00
1347	1332	1333	375.0	12.0	50.0	.00
1348	1319	1333	2100.0	12.0	50.0	.00
1349	1337	1339	4210.0	12.0	85.0	.00
1350	1328	1338	600.0	12.0	45.0	.00
1351	1338	1353	1000.0	6.0	35.0	.00
1352	1330	1334	450.0	16.0	110.0	.00
1353	1334	1339	225.0	16.0	110.0	.00
1354	1334	1335	1425.0	12.0	50.0	.00
1355	1339	1340	1425.0	12.0	50.0	.00
1356	1335	1340	225.0	16.0	110.0	.00
1357	1340	1341	1950.0	12.0	50.0	.00
1358	1335	1336	1950.0	12.0	50.0	.00
1359	1331	1335	450.0	16.0	110.0	.00
1360	1332	1336	450.0	12.0	50.0	.00
1361	1336	1341	225.0	12.0	50.0	.00
1362	1341	1342	675.0	12.0	50.0	.00
1363	1342	1345	300.0	12.0	50.0	.00
1364	1342	1343	900.0	12.0	55.0	.00
1365	1345	1346	900.0	12.0	75.0	.00
1366	1343	1346	300.0	12.0	55.0	.00
1367	1346	1347	450.0	12.0	55.0	.00
1368	1347	1348	600.0	12.0	55.0	.00
1369	1347	1344	300.0	12.0	55.0	.00
1370	1328	1350	2500.0	16.0	110.0	.00
1371	1353	1337	1500.0	6.0	80.0	.00
1372	1350	1351	2800.0	6.0	40.0	.00
1373	1352	1351	1000.0	6.0	40.0	.00
1374	1337	1352	1000.0	6.0	40.0	.00

A SUCCESSFUL GEOMETRIC VERIFICATION HAS BEEN COMPLETED

JUNCTION NUMBER	DEMAND	ELEVATION	CONNECTING PIPES
1100	.00	59.00	1101 1102 1107
1101	.38	165.00	1107
1102	.00	22.00	1102 1103 1104
1103	.49	88.00	1103 1105 1106
1104	.21	73.00	1104 1106 1108
1105	.43	91.00	1105
1106	.22	123.00	1108 1109
1107	.00	113.00	1109 1114 1121
1108	.00	220.00	1119 1120 1123
1109	.00	244.00	1117 1118 1124
1110	.00	210.00	1116 1117
1111	.00	190.00	1115 1116
1112	.52	145.00	1112 1113 1115
1113	.00	190.00	1112 1122
1114	.40	211.00	1111 1122
1115	.37	186.00	1111 1121
1116	.00	.00	1113 1114
1117	.00	220.00	1118 1123
1200	.00	200.00	1120 1201 1204
1201	.00	200.00	1110 1206
1202	.15	.00	1101 1207
1203	.00	148.00	1205 1206 1207
1204	.00	135.00	1201 1202 1203
1205	.30	135.00	1202 1208 1253 1265
1206	.20	130.00	1203 1205 1210

1207	.50	103.00	1204 1212 1256
1208	.00	70.00	1210 1214 1219 1255
1209	.38	29.00	1212 1213 1214
1210	.00	27.00	1213 1215
1211	.23	20.00	1217 1218 1226
1212	.00	34.00	1216 1217 1264
1213	.18	120.00	1216
1214	.00	16.00	1218
1215	.00	70.00	1219 1221 1222
1216	.00	70.00	1211 1221 1257
1217	.00	108.00	1223 1228
1218	.39	70.00	1208 1223 1224 1229
1219	.00	50.00	1209 1224 1225 1230
1220	.00	50.00	1222 1225
1221	.00	.00	1231
1222	.39	114.00	1231 1232 1235
1223	.00	62.00	1227
1224	.00	48.00	1229 1232 1233 1243
1225	.00	36.00	1230 1233 1234 1251
1226	.38	125.00	1235 1236 1242
1227	.00	66.00	1227 1236 1237
1228	.47	62.00	1228 1238
1229	.00	36.00	1238 1239 1241 1243
1230	.00	36.00	1239 1240 1245 1251
1231	.00	36.00	1226 1234 1240
1232	.40	36.00	1220 1237 1244
1233	.00	84.00	1246 1248 1249
1234	.00	35.00	1244 1246 1250
1235	.00	84.00	1241 1247 1248
1236	.38	83.00	1247 1305
1237	.00	83.00	1242 1249 1304
1238	.00	40.00	1250 1307
1239	.00	40.00	1245 1308
1240	.15	23.00	1259
1241	.21	155.00	1252 1254 1265
1242	.21	165.00	1254 1255
1243	.00	84.00	1209 1252 1253 1266
1244	.00	70.00	1211 1256 1266
1245	.00	100.00	1258 1259 1262
1246	.31	21.00	1215 1258 1261
1247	.18	86.00	1262 1263
1248	.16	48.00	1260 1261 1263 1264
1249	.47	74.00	1220 1257 1260
1301	.36	119.00	1301
1302	.00	130.00	1301 1302 1309
1303	.00	148.00	1302 1303 1310
1304	.00	83.00	1303 1304 1305 1306 1311
1305	.00	51.00	1306 1307 1313
1306	.00	120.00	1311 1312 1333
1307	.26	42.00	1312 1313 1314
1308	.00	169.00	1330
1309	.00	124.00	1309 1330 1331
1310	.00	87.00	1310 1331 1332 1339
1311	.54	70.00	1332 1333 1334 1340
1312	.46	54.00	1334 1335 1336 1343
1313	.00	43.00	1314 1315 1316
1314	.00	43.00	1316 1320 1335
1315	.00	43.00	1320 1321 1324
1316	.00	42.00	1324 1325 1328
1317	.00	48.00	1328 1329 1337
1318	.36	50.00	1336 1337 1345
1319	.00	45.00	1327 1329 1348
1320	.00	.00	1326 1327
1321	.00	25.00	1322 1323 1325 1326
1322	.00	25.00	1317 1321 1322
1323	.00	20.00	1308 1315 1317
1324	.00	19.00	1318 1319 1323
1325	.00	20.00	1318
1326	.00	10.00	1319
1327	.24	178.00	1338
1328	.37	90.00	1339 1341 1350 1370
1329	.00	94.00	1340 1341 1342

1330	.18	90.00	1342 1343 1344 1352
1331	.00	65.00	1344 1345 1346 1359
1332	.00	33.00	1346 1347 1360
1333	.00	30.00	1347 1348
1334	.00	150.00	1352 1353 1354
1335	.40	85.00	1354 1356 1358 1359
1336	.00	50.00	1358 1360 1361
1337	.52	122.00	1349 1371 1374
1338	.00	112.00	1350 1351
1339	.00	150.00	1349 1353 1355
1340	.00	85.00	1355 1356 1357
1341	.25	50.00	1357 1361 1362
1342	.00	80.00	1362 1363 1364
1343	.00	53.00	1364 1366
1344	.00	.00	1369
1345	.00	105.00	1363 1365
1346	.31	74.00	1365 1366 1367
1347	.00	.00	1367 1368 1369
1348	.00	46.00	1368
1350	.00	145.00	1338 1370 1372
1351	.00	139.00	1372 1373
1352	.00	139.00	1373 1374
1353	.00	143.00	1351 1371

OUTPUT SELECTION: ALL RESULTS ARE OUTPUT EACH PERIOD
10 VALUES ARE OUTPUT FOR MAXIMUM AND MINIMUM PRESSURES

THIS SYSTEM HAS 164 PIPES WITH 120 JUNCTIONS , 42 LOOPS AND 3 FGNS

THE DEMANDS ARE CHANGED FROM ORIGINAL VALUES BY A FACTOR = 1.50

THE RESULTS ARE OBTAINED AFTER 2 TRIALS WITH AN ACCURACY = .00125

College Hill Reservoir
Max Day Demands: 1.5 x Avg Day
LeedsHill-Herkenhoff, Inc. Job No: 9838.12 File: CHMD.DAT Date: 11/03/89

PIPE NO.	NODE NOS.		FLOWRATE	HEAD LOSS	PUMP HEAD	MINOR LOSS	VELOCITY	HL/1000
1101	1202	1100	1.25	.26	.00	.00	.90	.29
1102	1100	1102	.68	.12	.00	.00	.49	.10
1103	1102	1103	.98	.11	.00	.00	.70	.18
1104	1102	1104	-.29	-.27	.00	.00	-.37	-.10
1105	1103	1105	.64	1.94	.00	.00	.82	.56
1106	1103	1104	-.40	-.38	.00	.00	-.51	-.13
1107	1100	1101	.57	.60	.00	.00	.73	.45
1108	1104	1106	-1.01	-2.51	.00	.00	-1.29	-1.29
1109	1106	1107	-1.34	-2.92	.00	.00	-1.71	-1.77
1110	0	1201	3.59	.28	.00	.00	1.64	.69
1111	1114	1115	.73	27.83	.00	.00	3.72	18.55
1112	1112	1113	1.33	.98	.00	.00	.95	.33
1113	1112	1116	1.17	6.89	.00	.00	3.34	9.84
1114	1107	1116	-1.17	-23.62	.00	.00	-3.34	-9.84
1115	1111	1112	3.28	4.17	.00	.00	2.35	1.74
1116	1110	1111	3.28	.82	.00	.00	1.50	.59
1117	1109	1110	3.28	.23	.00	.00	1.50	.59
1118	1109	1117	.00	.00	.00	.00	.00	.00
1119	0	1108	13.10	.25	.00	.00	2.67	1.06
1120	1108	1200	13.10	.17	.00	.00	2.67	1.06
1121	1107	1115	-.17	-1.47	.00	.00	-.50	-.29
1122	1113	1114	1.33	.23	.00	.00	.95	.33
LINE 1123 IS CLOSED								
1124	0	1109	3.28	.78	.00	.00	2.35	1.74
1201	1200	1204	9.71	.17	.00	.00	1.37	.25
1202	1204	1205	9.31	.01	.00	.00	1.32	.23
1203	1204	1206	.39	.00	.00	.00	.15	.01
1204	1200	1207	3.39	.62	.00	.00	1.08	.26

1205	1206	1203	-2.11	-.12	.00	.00	-.80	-.16
1206	1201	1203	3.59	.20	.00	.00	1.36	.44
1207	1202	1203	-1.48	-1.36	.00	.00	-1.06	-.40
1208	1205	1218	5.82	.66	.00	.00	.82	.10
1209	1243	1219	1.86	.38	.00	.00	.59	.08
1210	1206	1208	2.20	.53	.00	.00	.83	.18
1211	1244	1216	1.70	.15	.00	.00	.54	.07
1212	1207	1209	1.68	.18	.00	.00	.54	.07
1213	1209	1210	1.56	.05	.00	.00	.50	.06
1214	1208	1209	.44	.10	.00	.00	.32	.04
1215	1210	1246	1.56	.53	.00	.00	1.11	.44
1216	1212	1213	.27	.33	.00	.00	.34	.18
1217	1211	1212	-.15	-.01	.00	.00	-.19	-.06
1218	1211	1214	.00	.00	.00	.00	.00	.00
1219	1208	1215	1.57	.07	.00	.00	.60	.09
1220	1249	1232	1.27	1.22	.00	.00	.91	.30
1221	1215	1216	.34	.00	.00	.00	.11	.00
1222	1215	1220	1.23	.15	.00	.00	.47	.06
1223	1218	1217	1.06	.11	.00	.00	.76	.21
1224	1218	1219	.84	.10	.00	.00	.60	.14
1225	1219	1220	-1.23	-.01	.00	.00	-.88	-.28
1226	1211	1231	-.20	-.84	.00	.00	-.25	-.20
1227	1223	1227	.00	.00	.00	.00	.00	.00
1228	1217	1228	1.06	.06	.00	.00	.34	.03
1229	1218	1224	3.34	.15	.00	.00	.68	.08
1230	1219	1225	3.93	.01	.00	.00	1.25	.34
1231	1222	1221	.00	.00	.00	.00	.00	.00
1232	1224	1222	1.66	.40	.00	.00	.76	.17
1233	1224	1225	-.91	-.04	.00	.00	-.42	-.05
1234	1225	1231	.74	.00	.00	.00	.34	.04
1235	1222	1226	1.08	.50	.00	.00	1.37	.83
1236	1227	1226	-.13	-.11	.00	.00	-.16	-.06
1237	1232	1227	-.13	-.09	.00	.00	-.16	-.06
1238	1229	1228	-.35	-.01	.00	.00	-.25	-.03
1239	1230	1229	.56	.05	.00	.00	.40	.07
1240	1230	1231	-.54	-.02	.00	.00	-.39	-.06
1241	1229	1235	3.50	1.26	.00	.00	1.60	.66
1242	1226	1237	.38	.46	.00	.00	.48	.14
1243	1224	1229	2.59	.03	.00	.00	1.19	.38
1244	1232	1234	.80	.20	.00	.00	.57	.13
1245	1230	1239	2.27	.50	.00	.00	.86	.19
1246	1233	1234	-.05	.00	.00	.00	-.04	.00
1247	1235	1236	2.20	.09	.00	.00	.70	.12
1248	1233	1235	-1.30	-.01	.00	.00	-.59	-.11
1249	1233	1237	1.35	.06	.00	.00	.62	.11
1250	1234	1238	.75	.03	.00	.00	.54	.11
1251	1225	1230	2.29	.02	.00	.00	.73	.12
1252	1243	1241	.20	.48	.00	.00	.57	.34
1253	1205	1243	2.80	.38	.00	.00	.89	.18
1254	1241	1242	.13	.17	.00	.00	.37	.15
1255	1242	1208	-.19	-.50	.00	.00	-.53	-.30
1256	1207	1244	.96	.01	.00	.00	.31	.02
1257	1216	1249	2.04	.09	.00	.00	.65	.10
1258	1246	1245	.27	1.93	.00	.00	.78	2.68
1259	1245	1240	.23	36.74	.00	.00	1.15	9.42
1260	1249	1248	.06	.83	.00	.00	.18	.22
1261	1246	1248	.82	.31	.00	.00	.59	.13
1262	1245	1247	.05	1.10	.00	.00	.25	.55
1263	1248	1247	.22	2.72	.00	.00	.63	1.81
1264	1248	1212	.42	.10	.00	.00	.30	.04
1265	1205	1241	.24	.85	.00	.00	.70	.50
1266	1243	1244	.74	.07	.00	.00	.53	.11
1301	1301	1302	-.54	-.41	.00	.00	-.69	-.90
1302	1302	1303	-.47	-.32	.00	.00	-.60	-.71
1303	1303	1304	-1.19	-.11	.00	.00	-.85	-.27
1304	1237	1304	1.72	.03	.00	.00	1.23	.53
1305	1236	1304	1.63	.01	.00	.00	.52	.07
1306	1304	1305	.32	.02	.00	.00	.23	.02
1307	1238	1305	.75	.07	.00	.00	.54	.11
1308	1239	1323	2.27	.93	.00	.00	1.63	.88
1309	1302	1309	-.07	-.05	.00	.00	-.09	-.02
1310	1303	1310	.71	.25	.00	.00	.51	.10

1311	1304	1306	1.85	.15	.00	.00	.85	.20
1312	1306	1307	-.09	-.04	.00	.00	-.12	-.03
1313	1305	1307	1.07	.10	.00	.00	.77	.22
1314	1307	1313	.59	.02	.00	.00	.42	.07
1315	1313	1323	-.86	-.11	.00	.00	-.61	-.15
1316	1313	1314	1.45	.11	.00	.00	1.04	.38
1317	1323	1322	1.41	.22	.00	.00	1.01	.37
1318	1325	1324	.00	.00	.00	.00	.00	.00
1319	1324	1326	.00	.00	.00	.00	.00	.00
1320	1314	1315	.26	.00	.00	.00	.19	.02
1321	1315	1322	-.35	-.01	.00	.00	-.25	-.03
1322	1321	1322	-1.06	-.02	.00	.00	-.40	-.05
1323	1321	1324	.00	.00	.00	.00	.00	.00
1324	1315	1316	.62	.04	.00	.00	.44	.08
1325	1316	1321	-.12	-.02	.00	.00	-.15	-.08
1326	1320	1321	-.94	-.05	.00	.00	-.36	-.04
1327	1319	1320	-.94	-.08	.00	.00	-.67	-.17
1328	1316	1317	.73	.13	.00	.00	.53	.11
1329	1317	1319	-.71	-.03	.00	.00	-.51	-.10
1330	1309	1308	.00	.00	.00	.00	.00	.00
1331	1310	1309	.07	.01	.00	.00	.09	.02
1332	1311	1310	-.33	-.16	.00	.00	-.42	-.36
1333	1306	1311	1.94	.37	.00	.00	.89	.22
1334	1311	1312	.17	.09	.00	.00	.21	.07
1335	1314	1312	1.18	.36	.00	.00	.85	.26
1336	1318	1312	.06	.03	.00	.00	.08	.02
1337	1317	1318	1.44	.15	.00	.00	1.03	.38
1338	1327	1350	-.36	-.01	.00	.00	-.26	-.03
1339	1310	1328	.32	.37	.00	.00	.40	.25
1340	1311	1329	1.29	.16	.00	.00	.59	.10
1341	1328	1329	-.73	-.05	.00	.00	-.52	-.11
1342	1329	1330	.57	.09	.00	.00	.40	.07
1343	1312	1330	.72	.16	.00	.00	.52	.11
1344	1330	1331	.24	.02	.00	.00	.17	.01
1345	1318	1331	.84	.21	.00	.00	.60	.14
1346	1331	1332	.14	.17	.00	.00	.17	.09
1347	1332	1333	-.23	-.08	.00	.00	-.30	-.23
1348	1319	1333	.23	.47	.00	.00	.30	.23
1349	1337	1339	-.65	-2.40	.00	.00	-.83	-.57
1350	1328	1338	.08	.02	.00	.00	.11	.04
1351	1338	1353	.08	1.89	.00	.00	.42	1.89
1352	1330	1334	.78	.06	.00	.00	.56	.12
1353	1334	1339	.70	.02	.00	.00	.50	.10
1354	1334	1335	.08	.04	.00	.00	.10	.03
1355	1339	1340	.05	.02	.00	.00	.07	.01
1356	1335	1340	.22	.00	.00	.00	.16	.01
1357	1340	1341	.27	.59	.00	.00	.35	.30
1358	1335	1336	.20	.33	.00	.00	.25	.17
1359	1331	1335	.94	.08	.00	.00	.67	.17
1360	1332	1336	.37	.24	.00	.00	.47	.53
1361	1336	1341	.57	.27	.00	.00	.72	1.18
1362	1341	1342	.47	.55	.00	.00	.59	.82
1363	1342	1345	.25	.08	.00	.00	.32	.26
1364	1342	1343	.21	.14	.00	.00	.27	.16
1365	1345	1346	.25	.11	.00	.00	.32	.12
1366	1343	1346	.21	.05	.00	.00	.27	.16
1367	1346	1347	.00	.00	.00	.00	.00	.00
1368	1347	1348	.00	.00	.00	.00	.00	.00
1369	1347	1344	.00	.00	.00	.00	.00	.00
1370	1328	1350	.41	.09	.00	.00	.29	.04
1371	1353	1337	.08	.61	.00	.00	.42	.41
1372	1350	1351	.05	1.42	.00	.00	.24	.51
1373	1352	1351	-.05	-.51	.00	.00	-.24	-.51
1374	1337	1352	-.05	-.51	.00	.00	-.24	-.51

JUNCTION NUMBER	DEMAND	GRADE LINE	ELEVATION	PRESSURE
1100	.00	252.91	59.00	84.03
1101	.57	252.30	165.00	37.83
1102	.00	252.78	22.00	100.01
1103	.74	252.67	88.00	71.36
1104	.31	253.06	73.00	78.02

1105	.64	250.74	91.00	69.22
1106	.33	255.57	123.00	57.45
1107	.00	258.49	113.00	63.04
1108	.00	254.75	220.00	15.06
1109	.00	294.22	244.00	21.76
1110	.00	293.98	210.00	36.39
1111	.00	293.16	190.00	44.70
1112	.78	288.99	145.00	62.40
1113	.00	288.01	190.00	42.47
1114	.60	287.78	211.00	33.27
1115	.56	259.95	186.00	32.05
1116	.00	282.10		
1117	.00	294.22	220.00	32.16
1200	.00	254.58	200.00	23.65
1201	.00	254.72	200.00	23.71
1202	.23	253.17		
1203	.00	254.53	148.00	46.16
1204	.00	254.41	135.00	51.74
1205	.45	254.39	135.00	51.74
1206	.30	254.40	130.00	53.91
1207	.75	253.96	103.00	65.41
1208	.00	253.87	70.00	79.68
1209	.57	253.77	29.00	97.40
1210	.00	253.72	27.00	98.24
1211	.34	252.78	20.00	100.87
1212	.00	252.79	34.00	94.81
1213	.27	252.46	120.00	57.40
1214	.00	252.78	16.00	102.60
1215	.00	253.80	70.00	79.65
1216	.00	253.80	70.00	79.65
1217	.00	253.63	108.00	63.11
1218	.58	253.74	70.00	79.62
1219	.00	253.64	50.00	88.24
1220	.00	253.65	50.00	88.25
1221	.00	253.19		
1222	.58	253.19	114.00	60.31
1223	.00	252.58	62.00	82.58
1224	.00	253.59	48.00	89.09
1225	.00	253.63	36.00	94.31
1226	.57	252.69	125.00	55.33
1227	.00	252.58	66.00	80.85
1228	.70	253.57	62.00	83.01
1229	.00	253.56	36.00	94.27
1230	.00	253.61	36.00	94.30
1231	.00	253.63	36.00	94.30
1232	.60	252.49	36.00	93.81
1233	.00	252.29	84.00	72.92
1234	.00	252.29	35.00	94.16
1235	.00	252.30	84.00	72.93
1236	.57	252.21	83.00	73.32
1237	.00	252.23	83.00	73.33
1238	.00	252.25	40.00	91.98
1239	.00	253.10	40.00	92.34
1240	.23	214.52	23.00	82.99
1241	.31	253.54	155.00	42.70
1242	.31	253.37	165.00	38.29
1243	.00	254.02	84.00	73.68
1244	.00	253.95	70.00	79.71
1245	.00	251.26	100.00	65.55
1246	.47	253.19	21.00	100.62
1247	.27	250.17	86.00	71.14
1248	.24	252.89	48.00	88.78
1249	.70	253.72	74.00	77.88
1301	.54	251.37	119.00	57.36
1302	.00	251.78	130.00	52.77
1303	.00	252.10	148.00	45.11
1304	.00	252.20	83.00	73.32
1305	.00	252.19	51.00	87.18
1306	.00	252.05	120.00	57.22
1307	.39	252.09	42.00	91.04
1308	.00	251.84	169.00	35.90
1309	.00	251.84	124.00	55.40

1310	.00	251.85	87.00	71.43
1311	.81	251.69	70.00	78.73
1312	.69	251.60	54.00	85.62
1313	.00	252.07	43.00	90.60
1314	.00	251.95	43.00	90.55
1315	.00	251.95	43.00	90.54
1316	.00	251.91	42.00	90.96
1317	.00	251.78	48.00	88.31
1318	.54	251.63	50.00	87.37
1319	.00	251.81	45.00	89.62
1320	.00	251.89		
1321	.00	251.94	25.00	98.34
1322	.00	251.96	25.00	98.35
1323	.00	252.18	20.00	100.61
1324	.00	251.94	19.00	100.94
1325	.00	251.94	20.00	100.51
1326	.00	251.94	10.00	104.84
1327	.36	251.37	178.00	31.80
1328	.56	251.48	90.00	69.97
1329	.00	251.53	94.00	68.26
1330	.27	251.44	90.00	69.96
1331	.00	251.42	65.00	80.78
1332	.00	251.25	33.00	94.58
1333	.00	251.34	30.00	95.91
1334	.00	251.38	150.00	43.93
1335	.60	251.34	85.00	72.08
1336	.00	251.01	50.00	87.11
1337	.78	248.96	122.00	55.01
1338	.00	251.46	112.00	60.43
1339	.00	251.36	150.00	43.92
1340	.00	251.34	85.00	72.08
1341	.38	250.75	50.00	86.99
1342	.00	250.19	80.00	73.75
1343	.00	250.05	53.00	85.39
1344	.00	250.00		
1345	.00	250.12	105.00	62.88
1346	.47	250.00	74.00	76.27
1347	.00	250.00		
1348	.00	250.00	46.00	88.40
1350	.00	251.39	145.00	46.10
1351	.00	249.97	139.00	48.09
1352	.00	249.46	139.00	47.87
1353	.00	249.57	143.00	46.18

MAXIMUM PRESSURES

1326	.00	251.94	10.00	104.84
1214	.00	252.78	16.00	102.60
1324	.00	251.94	19.00	100.94
1211	.34	252.78	20.00	100.87
1246	.47	253.19	21.00	100.62
1323	.00	252.18	20.00	100.61
1325	.00	251.94	20.00	100.51
1102	.00	252.78	22.00	100.01
1322	.00	251.96	25.00	98.35
1321	.00	251.94	25.00	98.34

MINIMUM PRESSURES

1108	.00	254.75	220.00	15.06
1109	.00	294.22	244.00	21.76
1200	.00	254.58	200.00	23.65
1201	.00	254.72	200.00	23.71
1327	.36	251.37	178.00	31.80
1115	.56	259.95	186.00	32.05
1117	.00	294.22	220.00	32.16
1114	.60	287.78	211.00	33.27
1308	.00	251.84	169.00	35.90
1110	.00	293.98	210.00	36.39

THE NET SYSTEM DEMAND = 19.97

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-) FROM FIXED GRADE NODES

PIPE NUMBER	FLOWRATE
1110	3.59
1119	13.10
1124	3.28

THE NET FLOW INTO THE SYSTEM FROM FIXED GRADE NODES = 19.97
THE NET FLOW OUT OF THE SYSTEM INTO FIXED GRADE NODES = .00